Juno Beach Shore Protection Project
Post-Construction Monitoring Report
Years 1, 2, and 3

Prepared For:

Palm Beach County and
Florida Department of Environmental Protection

Prepared By:

Applied Technology & Management, Inc.
400 S. Australian Avenue, Suite 855
West Palm Beach, Florida 33401

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Post-Construction Monitoring Report
Years 1, 2, and 3

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INTRODUCTION

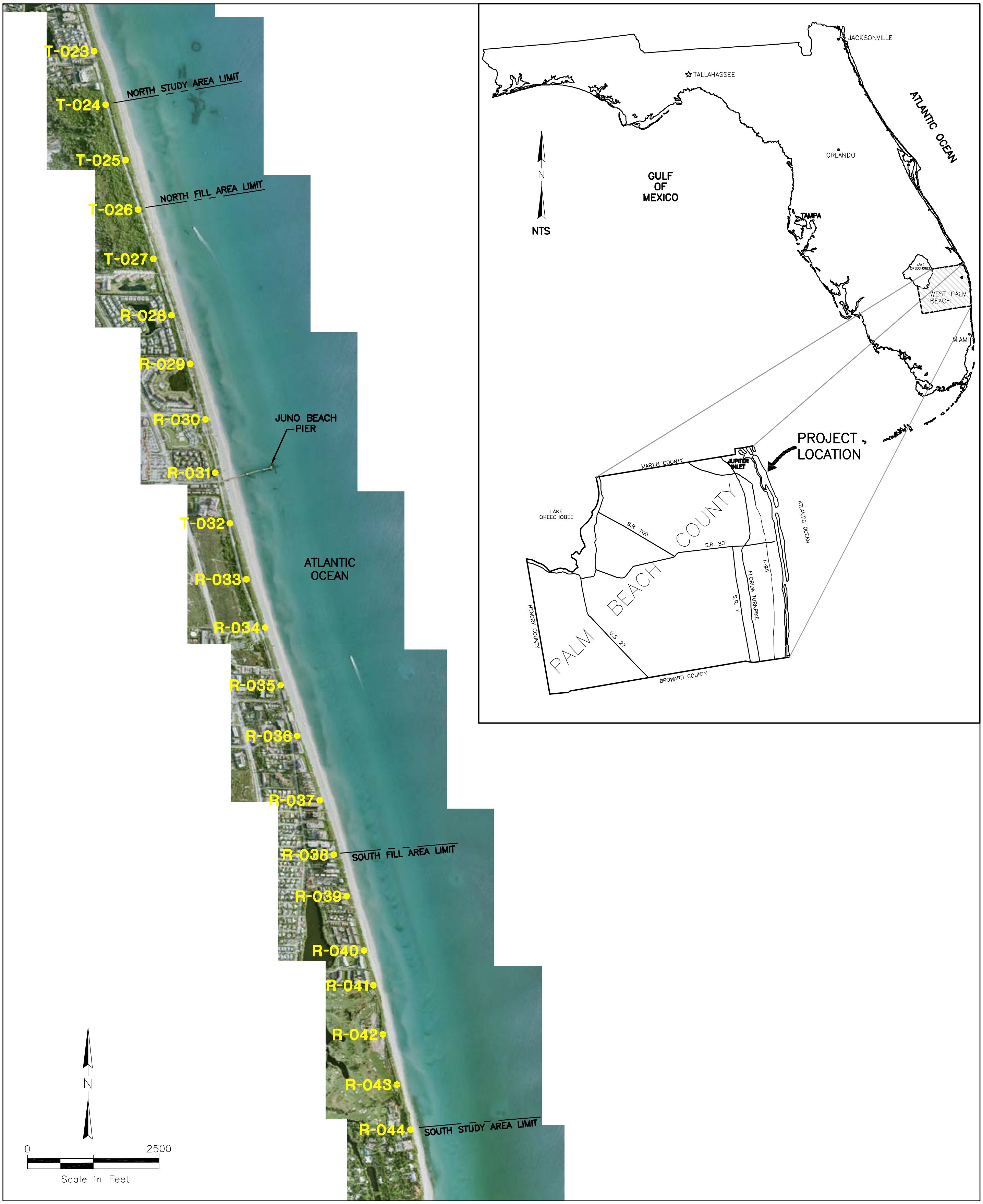
The Juno Beach Shore Protection Project was constructed between November 2000 and March 2001. The project restored approximately 12,810 feet (2.4 miles) of shoreline between the Jupiter Reef Club and the Juno Ocean Club (Florida Department of Environmental Protection Reference Monuments T-26 and R-38) with approximately 1 million cubic yards of beach compatible sand excavated from a borrow source located approximately 2 miles northeast of Jupiter Inlet. The project consisted of a uniform +9 ft. NGVD elevation (National Geodetic Vertical Datum) and an average 150-foot wide berm. The project was designed for a 6-year renourishment interval and included a new 30-foot wide dune which was vegetated with sea oats, trees, and other native dune plants. Additionally, an artificial reef was constructed in association with this project offshore of Florida Department of Environmental Protection (FDEP) Reference Monuments R-23, 24, and 25 to the north of the Juno Beach project area as mitigation for project impacts to the nearshore hardbottom.

The project area is shown in Figure 1.

This report presents the results of the 1, 2, and 3-year post-construction monitoring of the nourishment as required by the Florida Department of Environmental Protection Permit Number 0127642-001-JC.

AUTHORIZATION

This 1, 2, and 3-year post-project monitoring report was prepared for Palm Beach County and the FDEP Bureau of Beaches and Coastal Systems in compliance with monitoring requirements of the FDEP construction permit for the shore protection project. The Palm Beach County Department of Environmental Resources Management authorized the work described herein on September 29, 2004.



04-965 Figure 01.dwg Figure 1 4/25/05

Figure 1
Location Map
Juno Beach Shore Protection Project
2004 Aerial Photography

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PURPOSE AND SCOPE

The primary objectives of the 3-Year Post-Construction Monitoring Report are to:

1) Perform an engineering evaluation of the project's performance based on the 1, 2, and 3-year post-construction monitoring data;
2) Compare October 2002 survey data collected using the Laser Airborne Depth Sounder (LADS) method with October 2002 survey data collected using traditional survey methods; and,
3) Quantify the planform exposure of the natural and artificial nearshore hardbottom in the project area and identify any adverse impacts that may be attributable to the nourishment project.

POST-PROJECT BEACH MONITORING PLAN

The implementation of the Post-Project Beach Monitoring Plan is required to comply with the FDEP permit conditions and to evaluate the performance of the beach renourishment project based on measurements of physical conditions following project construction.

The primary components of the monitoring plan include:

1) Beach profile and hydrographic surveys of the project area and adjacent beaches (FDEP Reference Monuments R-24 through R-44 inclusive); and,
2) Vertical aerial photography along the limits of the surveyed beach.

Beach Profile and Hydrographic Surveys

Traditional beach and hydrographic survey methods are used to collect profile data annually as part of the Palm Beach County Annual Monitoring Survey Program. Wading beach profile portions are conducted using standard differential leveling techniques from the dune across the beach and seaward to a depth of approximately -6 ft. NGVD. Offshore portions of the profiles are conducted utilizing a survey vessel outfitted with a digital fathometer, a differential Global Positioning System (GPS), and navigational software. Offshore portions extend from the nearshore to a depth of approximately -30 feet NGVD. Offshore profiles are overlapped with the beach profiles in order to verify correct equipment operation and calibrations. Fathometer calibrations via 'bar checks' are performed periodically during surveys. Tidal corrections for vessel surveys are performed using a digital recording tide gage and tide staff, which were both surveyed into known vertical benchmarks. Tidal data are recorded for the duration of the vessel surveys and applied during data reduction to achieve elevations referenced to NGVD.

Survey transects originate at stations in the upland area of the beach as denoted by FDEP Reference Monuments (shown in Figure 1) and extend offshore along a set azimuth (degrees clockwise from magnetic north). Table 1 contains the northing and easting coordinates of the monuments within the study area in State Plane Coordinates National Atlantic Datum 83, the azimuths of the transects, elevation of the monuments relative to NGVD, and a description of the monuments.

Table 1. FDEP Reference Monuments.

Profile	Northing	Easting	Azimuth (deg.)	Elevation (ft. NGVD)	Description
	North American Datum 83/90				
T-24	938567.93	961296.54	75	24.74	T-24 1977 Reset 1999
T-25	937515.76	961673.13	75	25.64	DNR Disk 1977
T-26	936576.43	961907.13	85	27.04	5/8” IR/C
T-27	935639.95	962198.68	75	21.64	DESTROYED
R-28	934569.59	962540.61	80	21.37	DNR DISK 1989
R-29	933647.68	962895.84	80	25.51	CPE MON
R-30	932592.86	963188.95	80	22.89	DNR DISK 1974
R-31	931579.94	963371.22	80	21.48	DNR DISK 1989
T-32	930620.31	963653.49	80	23.82	DNR DISK 1977
R-33	929557.42	963965.87	75	22.71	DNR DISK 1974
R-34	928643.3	964321.67	75	14.12	DESTROYED
R-35	927546.47	964613.58	75	19.69	DNR DISK 1974
R-36	926586.58	964929.11	75	22.43	DNR DISK 1974
R-37	925366.28	965361.49	75	18.29	ME IRC PLS#4103
R-38	924330.77	965626.22	75	17.24	DNR DISK 1990
R-39	923545.2	965872.58	75	17.05	DNR DISK 1974
R-40	922511.24	966199.28	75	14.15	DNR DISK 1974
R-41	921851.18	966375.56	75	19.4	DNR DISK 1974
R-42	920922.59	966557.37	75	19.73	DNR DISK 1974
R-43	919965.23	966823.75	75	19.35	DNR DISK 1974
R-44	919112.98	967082.4	75	12.66	DNR DISK 1974

For the evaluation of the project performance, the October 2000 survey was used as the pre-construction survey and the January 2001 survey was used as the immediate post-construction survey. These data were collected using traditional beach and hydrographic survey methods.

Two survey data sets were used for the 1-year post-construction data. One set was collected in October 2002 using traditional survey methods, and the other set was collected nearly simultaneously in October 2002 using the Laser Airborne Depth Sounder (LADS) survey method. The traditional survey method data set included wading profiles surveyed at every FDEP Reference Monument in the project area and hydrographic survey data collected at every fifth monument out to a minimum of 2,000 feet offshore. Thus, to obtain a full data set for each profile in order to evaluate project performance, the wading profiles were merged with the LADS (nearshore and offshore portion) data set.

The 2 and 3-year post-construction data were collected in September 2003 and July 2004, respectively, using traditional survey methods. Appendix A contains beach profile comparison plots of all of the above-mentioned data for the study area.

Vertical Aerial Photography

Color vertical aerial photographs of the project area are also acquired annually as part of the Palm Beach County Countywide Annual Monitoring Survey Program and are required to be collected annually following project construction for two years by FDEP Permit No. 0127642-001-JC.

Aerials are flown at such a time of day as to minimize shadows and avoid glare, and at a time of near high tide and minimal wave heights in order to obtain clear and sharp images. The images are required to extend from the upland area to approximately 2,000 feet offshore. The images must be clear and provide enough detail to delineate the nearshore hardbottom. Palm Beach County uses the photographs and *in-situ* ground-truthing to identify areas of exposed hardbottom.

Aerial images of the project area collected in the summer of 2004 are used in this report.

COMPARISON OF LADS DATA

In October 2002, Palm Beach County beach profile data were collected using two different survey methods: traditional and LADS. These data were collected essentially concurrently between October 21st and November 5th. The traditional survey was conducted during the daytime and the LADS data were collected at night. No significant weather events occurred during the survey period.

The traditional method surveyed beach profiles collecting elevation data along cross-shore transects at FDEP Reference Monuments which are located at approximately 1,000 foot intervals along the shoreline. Data collection began in the dune/upland area of the beach and extended to approximately 2,000 feet offshore or to a depth of -30 ft. NGVD (whichever was further offshore). In the dune and beach area, data were collected at varying but frequent intervals to capture gradual and sudden changes in beach elevation and any features that were present such as the edge of vegetation, scarps, and seawalls. These intervals generally vary between 1 and 10 feet. Data were collected at approximately 20 to 25 foot intervals throughout the remainder of the profile.

The LADS survey of the study area included the upland area through the offshore area to a depth of approximately -180 ft. NGVD. The LADS survey method features rapid acquisition of bathymetric data using a laser shot from an airplane. The distance between the plane and the ocean floor was extrapolated from the time is takes for the laser to return. These data were collected at 4 meter (approximately 13 foot) spacing with tighter spacing in some areas along an approximately 800 foot swath below the plane. Thus, this survey method produced a dense data set that allowed for a detailed analysis of the ocean bottom configuration.

In order to compare these data sets, Palm Beach County extracted profile data from the large LADS data set to match the profile transects of the traditional survey. All LADS data within 5 feet of the traditional profile survey transects, as defined in Table 1, were extracted from the data set. The profile data collected by traditional survey methods was limited to wading profiles for all FDEP Reference Monuments in the County combined with hydrographic data collected only at every fifth monument. Only four profiles (T-25, R-30, R-35, and R-40) within the study area were surveyed with both beach and hydrographic survey methods and thus, are the only full-data profiles (extending beyond wading depth) available from the 2002 traditional survey data set for comparison with the LADS data set.

These four profiles were used for detailed comparison of the data measured with the traditional survey method to the data measured from the LADS survey method. Figures 2, 3, 4, and 5 show the profile comparisons at T-25, R-30, R-35 and R-40. A visual comparison of all the wading profiles to the LADS data was also conducted. Profile comparisons of these profiles are presented in Appendix C.

Comparison of the T-25, R-30, R-35, and R-40 profiles shows that both data sets are in good general agreement, following similar trends. However, large differences in individual profile comparisons can be seen. Comparison of the wading profiles shows a similar trend of good general agreement of the beach area with large differences in the dune and berm areas.

The profile differences in the dune and berm areas are likely due to the different methods by which the survey techniques measure the topography in areas of vegetation and changes in slope. The LADS survey method measures elevation at set intervals and identifies the highest point in that area, thus, it may ‘smooth over’ sharp features such as scarps or seawalls, and is likely to identify an elevation at the top of the vegetation, not the underlying sand. The LADS method will also return inconsistent data when the laser beam encounters a slope. If the elevation is being measured at an angle, many elevations will be measured by the beam for a single point and a single average data point will be returned. Additionally, the LADS method uses the water surface in the determination of elevation, thus, the data are inconsistent in areas of shallow water and on the dry beach and dune. Comparison of the four full profiles and the wading profiles in these areas shows this inconsistency where the LADS data differ in elevation (higher or lower) from the traditional survey by as much as 1 ½ feet in elevation. Because a survey crew is present to measure elevations on the beach and dune for the traditional survey method, they can concentrate measurements where there are distinct changes in elevation such as scarps, and they measure the elevation of the sand in vegetated areas. Comparison of profile cross-sections of successive traditional surveys shows a distinct repeatability in the data that is not present in the LADS data.

This is supported by profile comparisons in the beach, dune, and nearshore area. Figures 2, 4, and 5 show that the data sets show poor correlation in the beach and nearshore areas and separate at the vegetation line in profiles T-25, R-35, and R-40. Analyses of the wading profile comparisons in Appendix C also show a separation of the survey data sets in the vicinity of the dune vegetation and poor correlation in the dry beach areas. Note that the edge of vegetation noted on Figures 2 – 5 as well as on the wading profiles in Appendix C was determined from 2004 aerial data.

Berm differences seen in T-25 and R-35 are not likely to be real features that occurred between the surveys as the data were collected essentially concurrently and there were no significant weather events during the survey period. Comparison of successive traditional surveys at R-35 show a consistent berm and dune between 2002 to 2004 while the LADS data show a difference in elevation of 1 ½ feet. Because of the repeatability of the traditional survey data, it appears that the discrepancy in the LADS data is due to the LADS method of data collection.

Thus, while LADS data present a comprehensive representation of an area's topography, in specific areas of vegetation, shallow water, dry sand, or distinct grade change, the data need to be viewed with an understanding of this smoothing effect and lack of repeatability of the data.

While similar trends are noted in these four traditional and LADS profiles, notable differences are also observed. Inherent errors can be identified in both methods of data collection. For instance, the traditional survey method uses a boat to collect data below the -6 ft. NGVD contour and thus, is subject to waves, tides, and currents that need to be accounted for in the boat elevation at the time of the survey and thus the elevation of the profile data. In addition, the boat is difficult to maintain exactly on the profile azimuth while collecting data due to waves and currents. It should be noted that the exact difference in the azimuths of these data is unknown as the traditional survey data that were submitted to the County had been artificially aligned to the designated profile azimuth by the surveyor. Other data sets have shown that data are collected as much as 200 feet offline of the designated profile azimuth. If the data are collected along different azimuths, each survey may identify different features such as the nearshore bar feature captured by the LADS survey at R-35 but not documented by the traditional survey. This may also be the root of the discrepancies in some of the elevation differences in the profile data.

Alternately, the LADS data are very noisy, returning alternating high and low points that differ by 1 foot or more throughout the profiles. These data irregularities are not believed to represent real features, particularly in the offshore region where sandy bottom features of the size and density of those indicated by the LADS data are uncommon. It should also be noted that no hardbottom is present in the vicinity of these profiles and thus, would not be the cause of the differences in the profiles. In addition to successive high and low points, the LADS data contains many data points in which a high and low elevation are reported for the exact *same* location.

Additional differences in the data may be due to the resolution of the data. The LADS method collect data at 4-meter (approximately 13 foot) intervals and the traditional survey methods collect data at approximately 10 foot intervals in the wading portions and 25 foot intervals in the offshore portions of the profiles.

Detailed comparisons of the profile data at T-25, R-30, R-35, and R-40 are presented below along with figures showing the traditional and LADS profile data. Appendix C of this report contains comparison plots of the wading profiles and the LADS profiles.

T-25

ProfileT-25 (Figure 2) shows that the data are in good agreement with consistent general shapes. The LADS profile is slightly higher than the traditional survey profile above Mean High Water (MHW) and alternates between being higher and lower than the traditional survey throughout the profile below MHW. Differences in elevations are noted in the dry beach/berm area with an approximate 1 foot vertical difference, and in the nearshore with an approximate 1 foot vertical difference in elevation. A maximum difference in the surveys of 13.2 c.y./ft. was noted near the -10 ft. NGVD contour in which the LADS profile followed the trend of the traditional survey, but depicts approximately 1 foot lower elevations. The net volumetric difference in the surveys (excluding vegetated area) shows the LADS data representing 3.4 c.y./ft. more than the traditional data between the dune and MHW and 16.0 c.y./ft. more between MHW and the -18 ft. NGVD contour with an average elevation difference of 0.2 ft. between the dune and the -18 ft. NGVD contour.

R-30

Profile R-30 (Figure 3) shows good general agreement, especially in the beach and berm areas, with notable inconsistencies in the nearshore and offshore areas. The LADS profile is slightly higher than the traditional survey profile above MHW and alternates between being higher and lower than the traditional survey throughout the profile below MHW. Minor differences (less than a foot) can be seen in the elevations in the dune and berm areas and the LADS data appear to have noted a small bar feature in the nearshore (~1 ft. vertical difference) that was not documented in the traditional survey. As the data were collected essentially concurrently, it is not likely that this bar was formed between the data set collections. Additionally, there are two areas in the near and offshore regions of the profile where the two data sets do not compare well with elevation differences of approximately 1 ½ feet.

04-965 Figure 02 thru 05.dwg Figure 2 4/25/05

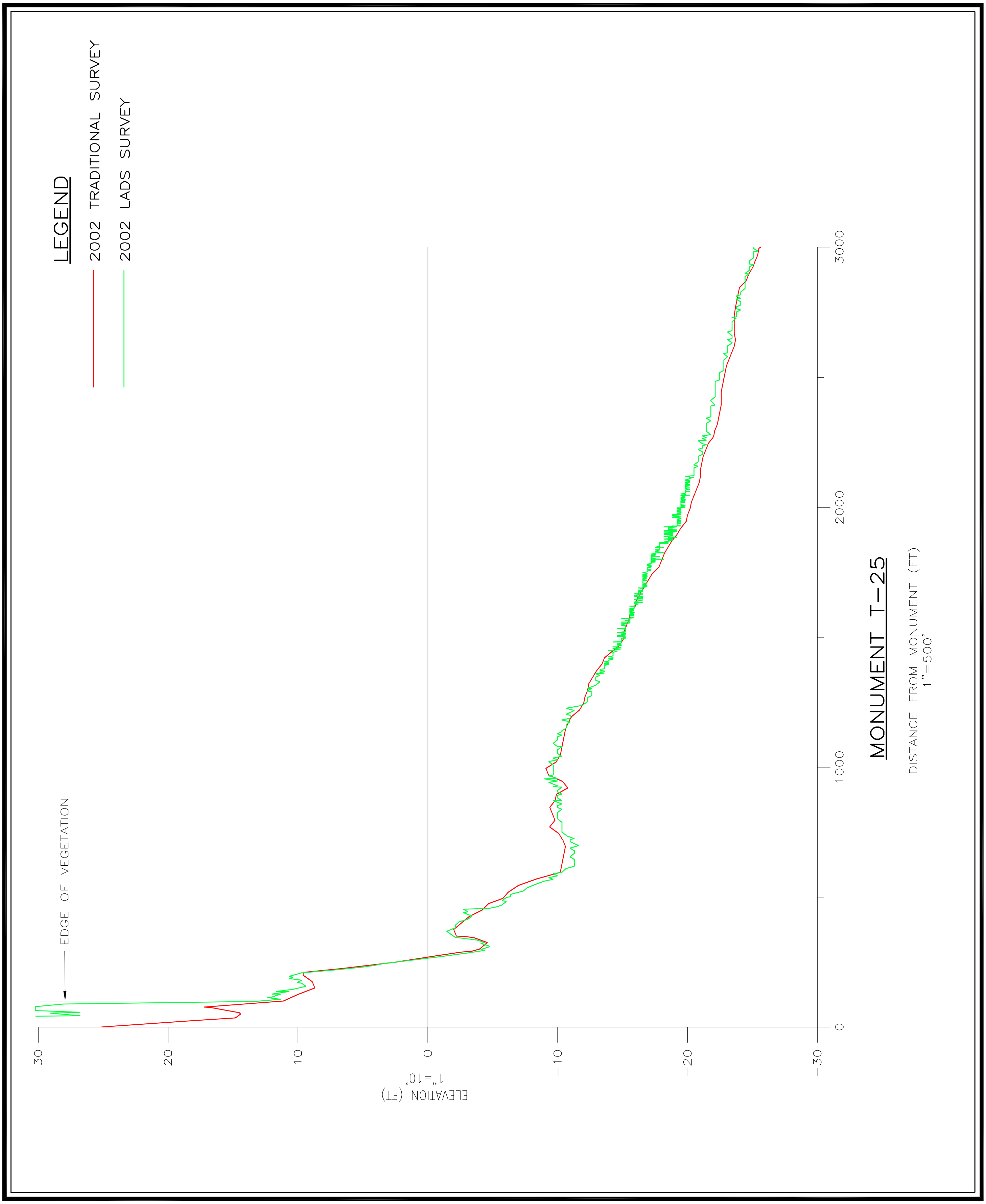

Figure 2
T-25 Comparison of LADS Data and Traditional Survey Data
Juno Beach Shore Protection Project

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04-965 Figure 02 thru 05.dwg Figure 3 4/25/05

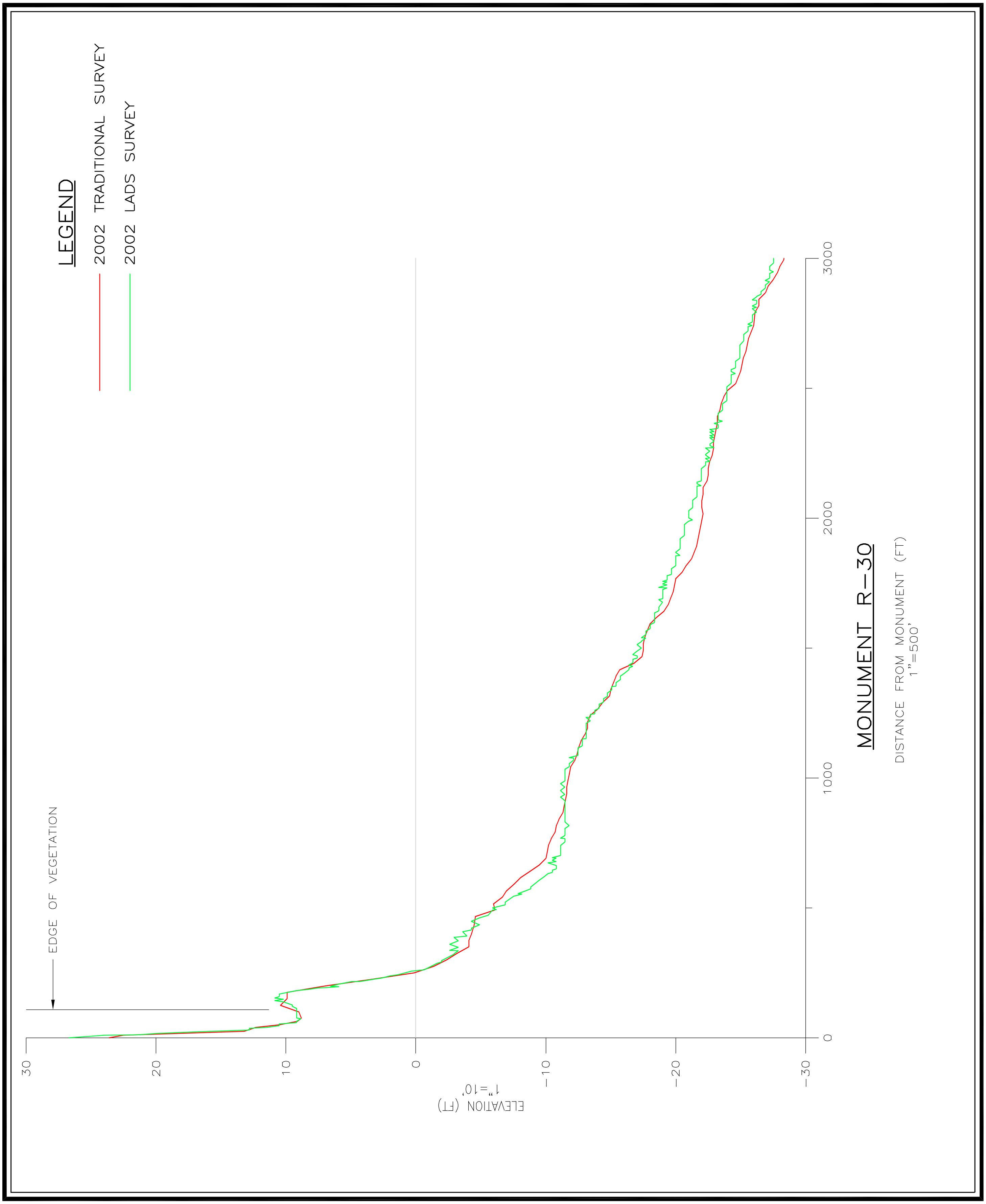

Figure 3
R-30 Comparison of LADS Data and Traditional Survey Data
Juno Beach Shore Protection Project

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04-965 Figure 02 thru 05.dwg Figure 4 4/25/05

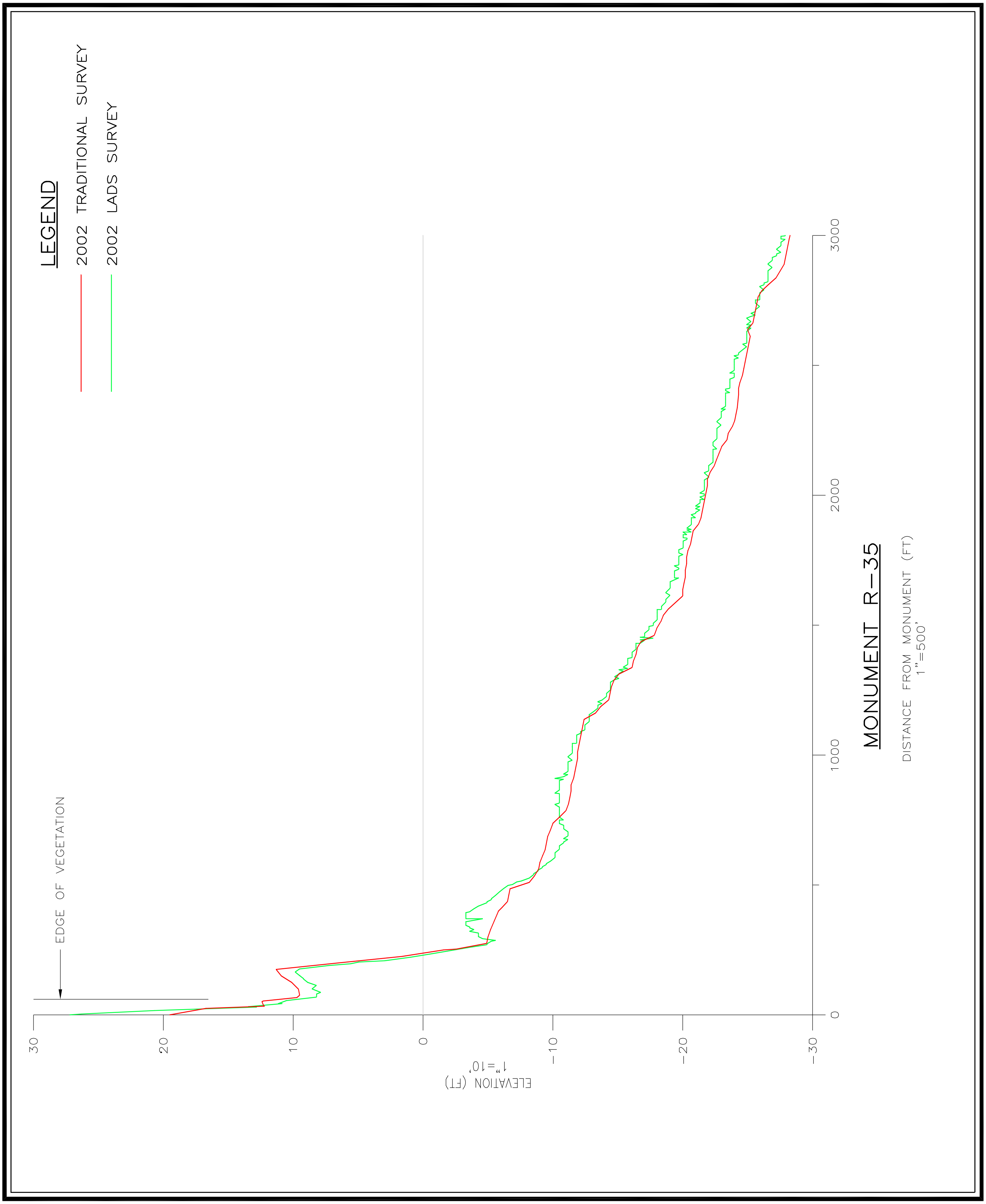

Figure 4
R-35 Comparison of LADS Data and Traditional Survey Data
Juno Beach Shore Protection Project

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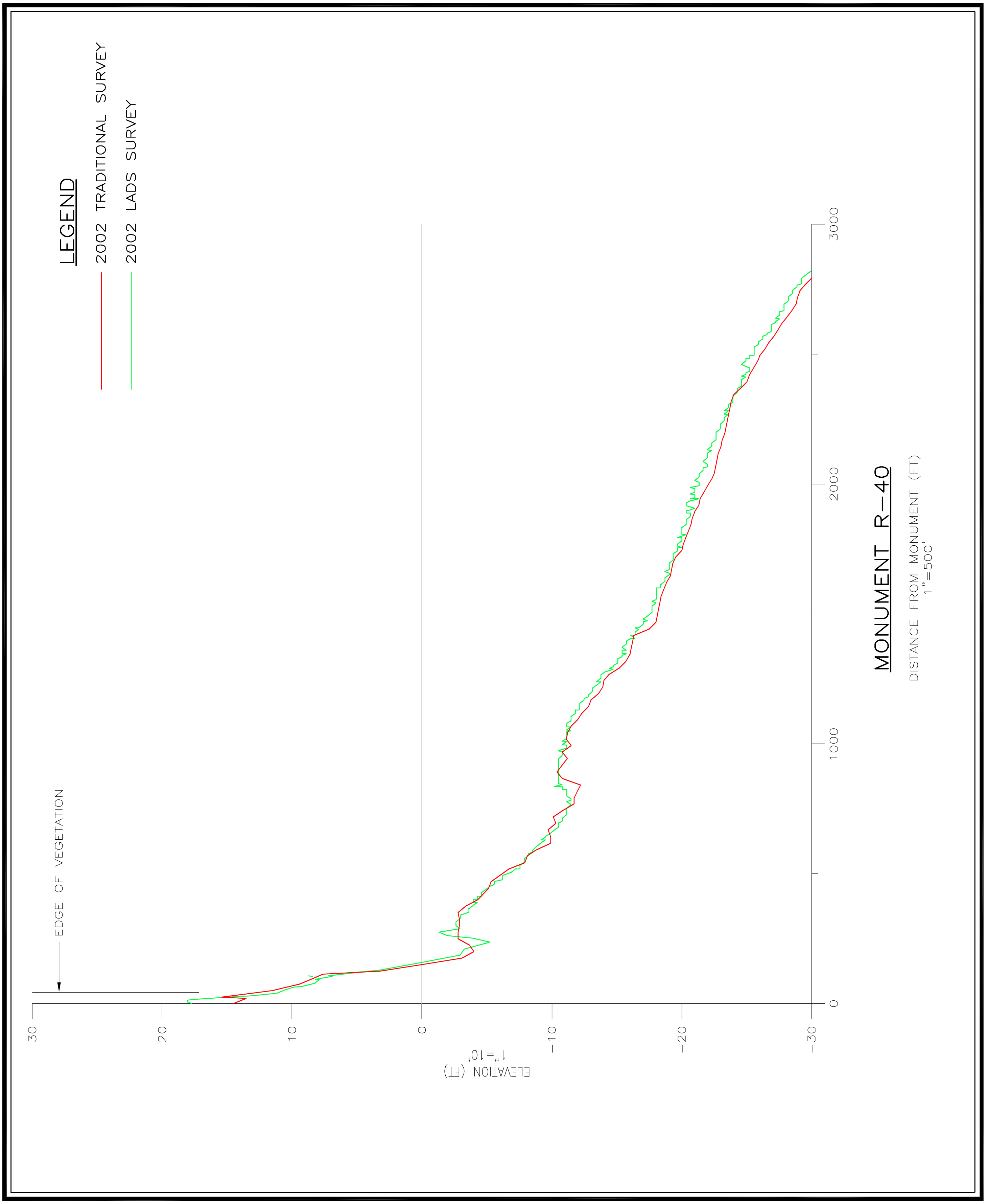

Figure 5
R-40 Comparison of LADS Data and Traditional Survey Data
Juno Beach Shore Protection Project

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The nearshore area shows a difference in the profiles of 14.2 c.y./ft. around the -10 ft. NGVD contour. In the offshore region, there is another area in which the elevation difference is approximately 1 ½ feet with a volumetric difference of 17.7 c.y./ft. This deviation in the survey data occurs between the -19 ft. and -23 ft. NGVD contours. Along the study area, it was determined that minimal changes occur below the -18 ft. NGVD contour. The difference below the -18 ft. NGVD contour in this instance may be due to differing profile azimuths of the LADS and traditional survey data. It has been documented that the accuracy of fathometer data at -30 ft. NGVD is +/- 0.3 feet, however, this is not likely the cause of this discrepancy as the difference is much larger than 0.3 ft., and similar differences appear in this area of profiles R-35 and R-40.

A maximum difference in the surveys of 17.7 c.y./ft. was noted in the offshore as described above near the -21 ft. NGVD contour. The net volumetric difference in the surveys shows the LADS data representing 1.0 c.y./ft. more than the traditional data between the dune (excluding vegetated area) and MHW and 9.8 c.y./ft. less between MHW and the -18 ft. NGVD contour with an average elevation difference of 0.15 ft. between the dune and the -18 ft. NGVD contour.

R-35

Profile R-35 (Figure 4) shows poor agreement throughout most of the profile. Excluding the vegetated area of the profile, the LADS profile is slightly lower than the traditional survey profile above MHW and is generally higher than the traditional survey throughout the profile below MHW. Significant differences are noted in the vegetated area of the dune, the dry beach/berm (approximately 1 ½ ft. elevation), in the nearshore regions of the profile (approximately 2 ft. elevation), and throughout the offshore portion of the profile (approximate 1 ft. elevation difference).

Comparison of the 2002, 2003, and 2004 traditional surveys at R-35 show a consistent berm and dune. Because of the repeatability of the traditional survey data, it appears that the discrepancy in this comparison is in the LADS data.

The difference in survey data in the berm area is 10.7 c.y./ft. and the LADS data indicates a 2-foot high sand bar feature in the nearshore that was not documented in the traditional survey representing a 12.1 c.y./ft. difference, plus a ridge/runnel feature a little further offshore with 1 ½ foot elevation and 6.9 c.y./ft. difference from the traditional survey data.

The maximum difference in the surveys is the 12.1 c.y./ft. noted in the nearshore. The net volumetric difference in the surveys shows the LADS data representing 9.4 c.y./ft. less than the traditional data between the dune (excluding vegetated area) and MHW and 14.8 c.y./ft. more between MHW and the -18 ft. NGVD contour with an average elevation difference of 0.1 ft. between the dune and the -18 ft. NGVD contour.

R-40

Profile R-40 (Figure 5) shows minor vertical differences (1 foot or less) at various places throughout the profile and the data are in good agreement with consistent general shapes. The LADS profile is slightly lower than the traditional survey profile above MHW and is generally higher than the traditional survey throughout the profile below MHW. A maximum difference in the surveys of 17.2 c.y./ft. was noted between the -16 ft. and the -23 ft. NGVD contours in which the LADS profile followed the trend of the traditional survey, but depicts higher elevations for a distance of approximately 1,000 feet. The net volumetric difference in the surveys (excluding vegetated area) shows the LADS data representing 3.0 c.y./ft. less than the traditional data between the dune and MHW and 13.6 c.y./ft. more between MHW and the -18 ft. NGVD contour with an average elevation difference of 0.19 ft. between the dune and the -18 ft. NGVD contour.

Comparison Conclusion

The average net volumetric difference in the surveys between the dune (excluding the vegetated areas) and the -18 ft. NGVD contour is 0.1 c.y./ft. This would result in an overall volume difference in 1,540 c.y. over the length of the project when calculated using the weighted average end area method. This method uses the volumetric difference of each profile in the study area multiplied by the area of influence of that profile (shoreline length) to determine the total volume difference over the length of the study area. Despite the minor overall difference between surveys between the dune and DOC, the volumetric difference above MHW is 49,860 c.y. with the traditional survey data indicating higher volumes than the LADS data, and the difference below MHW is 51,400 c.y. with the LADS data indicating higher volume than the traditional survey data. Thus the volumetric difference between the surveys is significant despite the net difference in the data.

As described above, the LADS data sets are much more comprehensive than the traditional profile data and allows for a detailed analysis of ocean bottom configurations. The LADS method typically collects data at intervals in an approximately 800-foot wide swath, in successive swaths to obtain continuous data along the target area. The density of the LADS data produce an excellent view of the shape of the surface of the entire ocean floor in the survey area. Because of this abundance of information, LADS data have the potential to produce a more accurate evaluation of the changes in the beach and offshore areas and project performance using a surface analysis to compare successive LADS and/or LIDAR surveys, in contrast with the traditional method of extrapolating data between profile transects that is typically collected along transects at approximate 1,000 foot spacing across the survey area.

However, differences in the vegetated and dry beach areas of the profiles were noted and are believed to be attributed to inaccuracies in the LADS method of data collection. The LADS survey method measures elevation at set intervals and identifies the highest point in that area, thus, it may ‘smooth over’ sharp features such as scarps and seawalls, and is likely to identify an elevation at the top of the vegetation, not the underlying sand. The LADS method will also return inconsistent data when the laser beam encounters a slope. If the elevation is being measured at an angle, many elevations will be measured by the beam for a single point and a single average data point will be returned. Additionally, the LADS method uses the water surface in the determination of elevation, thus, the data are inconsistent in areas of shallow water and on the dry beach and dune. Because a survey crew is present to measure elevations on the beach and dune for the traditional survey method, they can concentrate measurements where there are distinct changes in elevation such as scarps, and measure the elevation of the sand in vegetated areas. Thus, while LADS data present a comprehensive representation of an area's topography, in specific areas of vegetation, shallow water, dry sand, or distinct grade change, the data need to be viewed with an understanding of this smoothing effect and lack of repeatability of the data. A smaller laser point, as used with terrestrial LIDAR, may provide better results for the upland land and dry beach portion of the survey.

The accuracy of the differing survey techniques in the offshore region is less clear as potential errors in both techniques can be identified. Traditional survey methods are subject to waves, tides, and currents that need to be accounted for in the boat elevation at the time of the survey and thus the elevation of the profile data. The waves, tides, and currents also tend to cause the boat to drift off of the profile azimuth during surveying so data are often collected offline of the designated transect. Data collected along differing azimuths can depict different features as well as different elevations. Alternately, the data irregularities in the form of a succession of high and low elevations contained within the LADS data are not likely representative of the natural irregularities in the offshore regions of the sandy bottom profiles.

The results of this quantitative comparison indicate that the LADS data do not accurately capture the features of the dry beach and dune areas. Literature on the LADS survey method suggests that the dry beach area may require data collection from a different altitude than that of the data below mean sea level. It is recommended that this aspect of the survey technique be further researched to optimize future data collection. It is also recommended that a closer spacing be used for data collection in these areas and that due to the limitations of the LADS data in vegetated areas, the limits of vegetation be manually identified and all data occurring in the vegetation area be eliminated from data comparisons. Further, it is recommended that LADS data be subject to additional processing by the surveyor to interpret the data and smooth the 'noise' in the data by eliminating false successive and same-location alternating high and low elevations. A comparison of successive LADS surveys in the same study area may provide additional information on the potential usefulness of LADS data as an analysis tool, however, the current lack of repeatability of data collection in shallow water and dry beach areas should be taken into consideration in such a study.

Due to the differences in the data from these two survey methods as noted in this comparison and the potential for significant volume differences in this method of evaluation, comparison of LADS data with traditional survey data to measure project performance and perform shoreline and volume calculations is not recommended until the issues noted herein are adequately addressed. Despite this recommendation, due to the incompleteness of the 1-year post-project traditional survey, the LADS data were merged with the 2002 wading profile data, and used in the analysis of project performance below.

POST-PROJECT CONDITIONS

To evaluate the performance of the beach restoration project and the trends in shoreline erosion and accretion, beach profile data are analyzed by comparing shoreline position and volume between the pre- and post-construction profiles.

The project placed approximately 1 million cubic yards of compatible sand on the beach between FDEP Reference Monuments T-26 and R-38, along approximately 12,800 feet (2.4 miles) of the shoreline. The average fill volume placed along the project area was 79.0 c.y./ft.

After artificially placing sand on a beach, the beach is naturally shaped in response to localized waves, wind, currents, and tides. The redistribution of sand, or equilibration, generally occurs within the first year after placement, thus, we can expect to see large changes when comparing the pre-construction and 1-year post-construction data and lesser changes between subsequent post-construction surveys.

Equilibration is characterized by longshore and cross-shore spreading of the beachfill. The longshore spreading can most easily be seen in shoreline changes, advancement of the shorelines in the adjacent beaches and recession of the shoreline in the fill placement area. Cross-shore spreading can most easily be observed by comparing subsequent profile cross-sections, as presented in Appendix A, and volumetric comparisons of the profiles above and below mean high water. The beachfill will move from the beach to the nearshore during equilibration.

It is important to note in this analysis that the pre-construction and 1-year post-construction data were collected in the fall and winter months and the immediate post-construction, and 2^{nd} and 3^{rd} year post-construction data were collected in the spring and summer months, and thus, some of the changes observed may also be attributed to seasonal changes. Seasonal variations typically include high wind and wave activity causing the formation of a steeper beach, while calmer wind and wave conditions tend to shape the beach into a wide, flat beach.

For this analysis, the study area includes the shoreline between FDEP Reference Monuments T-24 and R-44.

Beach Profile Shoreline Positions

The change in the location of MHW during subsequent surveys is used in this analysis as an indicator of project performance. The MHW elevation for the study area is +1.93 ft. NGVD (FDEP, 2001). Table 2 presents a summary of the shoreline changes for the study area by profile. The study area was broken out into three segments in Table 2 in order to evaluate project performance: north of the project area, project area, and south of the project area. Table 2 presents the changes when comparing pre-construction data with the immediate post-construction data, the 1-year post-construction (traditional) data, the 2-year post-construction data, and the 3-year post-construction data.

The weighted average in Table 2 was calculated using the shoreline change at each profile multiplied by the area of influence of that profile (shoreline length). The sum of these for each segment is then divided by the total shoreline length in that segment to determine the average shoreline change.

Figure 6 presents a graphical comparison of the shoreline positions along each profile in the study area at the time of pre-construction, immediate post-construction, 1-year post-construction, 2-years post-construction, and 3-years post-construction. Results of the placement can be seen in shoreline advance in the project area between the pre-construction shoreline and immediate post-construction shoreline with recession in subsequent years. While little changes in the shoreline are noted downdrift of the project area, shoreline changes are noted updrift of the project, despite the net southerly littoral drift in this area.

North of Project Area

Profiles T-24 and T-25 are located north of the project area.

Table 2 shows shoreline advancement between the pre-construction survey and all subsequent surveys. The advancement between the pre-construction survey and the immediate post-construction survey is not likely due to project spreading because of the short timeframe between the surveys and small placed volume in the north end of the project. The advancement is more likely due to seasonal variations in the data as the pre-construction data were collected in the fall and the post-construction data were collected in the spring. Profile cross-sections indicate an oddity in the 2001 data in which an approximately 8 foot high ridge/runnel feature is documented in the beach area of the profile. This is not believed to be a real feature but a data error. Thus, evaluation of project performance based on shoreline changes for the 2001 survey is not recommended for this section of the beach.

The shoreline advancement between the pre-construction survey and the 1-year post-construction survey is indicative of project spreading. Table 2 denotes more advancement at profile T-25 than T-24, as expected as the project spreads to the beach updrift of the project area. Additional shoreline advance is noted in years 2 and 3 post-construction; however, the majority of the shoreline advance is likely due to seasonal differences in the shorelines as observed by the wider dry beach seen in the 2003 and 2004 profile cross-sections when compared to the pre-construction profile cross-sections (Appendix A).

Table 2. Mean High Water Shoreline Changes

FDEP Reference Monument	Shoreline Changes (ft.)			
	Pre-Construction (2000) to Immediate Post-Construction (January 2001)	Pre-Construction (2000) to 1-Year Post-Construction (2002)	Pre-Construction (2000) to 2-Years Post-Construction (2003)	Pre-Construction (2000) to 3-Years Post-Construction (2004)
North of Project Area				
T-24	27.2	18.0	75.5	31.7
T-25	30.3	65.1	63.6	105.7
weighted average	**30**	**53**	**67**	**86**
Project Area				
T-26	62.0	101.8	118.8	101.4
T-27	138.3	116.0	127.7	80.7
R-28	152.0	108.2	108.1	73.7
R-29	158.0	110.0	113.8	103.7
R-30	165.1	114.0	131.6	112.3
R-31	111.9	70.8	102.3	57.4
T-32	158.8	74.4	117.3	122.1
R-33	201.2	161.0	191.0	174.4
R-34	194.7	151.8	162.4	152.3
R-35	131.3	87.7	122.5	120.6
R-36	154.8	146.4	146.9	133.3
R-37	150.0	100.8	86.5	96.6
R-38	68.7	82.5	46.1	32.4
weighted average	**149**	**111**	**124**	**108**
South of Project Area				
R-39	31.7	56.4	33.8	37.5
R-40	45.0	0.3	36.4	56.6
R-41	-6.9	-19.2	6.6	-9.8
R-42	0.2	-9.9	11.9	6.5
R-43	13.8	2.4	-2.9	-11.9
R-44	-12.4	16.3	-12.2	-6.1
weighted average	**16**	**11**	**16**	**16**

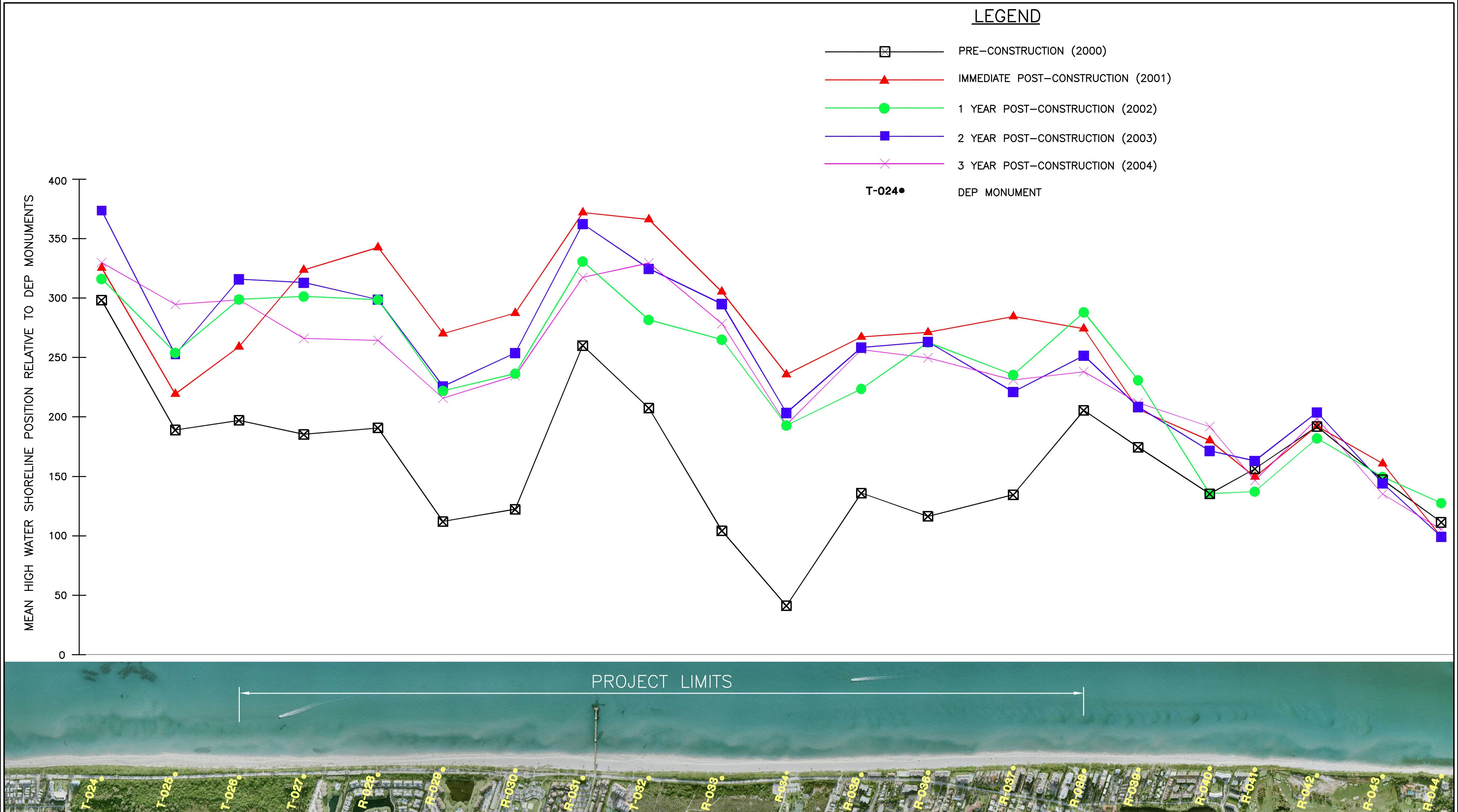

Figure 6
MHW Shoreline Positions
Juno Beach Shore Protection Project
2004 Aerial Photography

04-965 Figure 06.dwg Figure 6 4/25/05

Project Area

The project area includes the shoreline between T-26 and R-38. Between October 2000 and January 2001, the Juno Beach Shore Protection Project placed approximately 1 million cubic yards of beach compatible sand along this shoreline. The average fill volume placed along the project area was 79.0 c.y./ft.

Table 2 shows that the shoreline gained an average of approximately149 feet between the pre-construction survey and the immediate post-construction survey due to the sand placement activities. The project area generally shows shoreline recession during subsequent post-construction surveys as the shoreline was experiencing equilibration. However, the northern end of the project notes shoreline advancement post-construction as the project spread updrift as described above. At the 3-year post-construction survey, the equilibrated shoreline shows an advancement of an average of 108 feet from the pre-construction survey.

Year 1 post-construction data show shoreline advancement at T-26 as the project spreads into the northern project area and updrift beach. The remainder of the profiles in the project area show shoreline recession between the immediate post-construction survey and the 1-year post-construction survey, as expected as the project equilibrates.

The 2nd year post-construction survey indicates that the majority of the profiles experienced shoreline recession since the immediate post-construction survey and shoreline advancement between the 1-year and 2-year surveys. This apparent advancement could likely be due to storm swell from various hurricanes approaching the southeastern U.S. during the storm season. The 1-year post-construction data were obtained in October 2002 and the 2-year post-construction data were obtained in the September 2003. The profile cross-sections (Appendix A) show that most of the 2003 dry beach width is wider than the 2002 profiles.

The data for T-26, however, show more shoreline advancement at year 2 than at the immediate post-construction survey. Some of this advancement may be due to project spreading as shoreline advancement is also notable in the updrift study area.

Because the 2nd and 3rd year post-construction data were collected at the same time of the year, the shoreline recession trend is apparent between year 2 and year 3 post-construction.

Also apparent in the cross-sections is the shifting of the nearshore bar feature that is present for all profiles in the project area.

South of the Project Area

The area immediately to the south of the project area between R-39 and R-44 was also evaluated for shoreline changes.

Table 2 shows that the shoreline gained an average of approximately 16 feet between the pre-construction survey and the immediate post-construction survey. It is possible the that advances seen at R-39 and R-40 are due to project spreading, but it is not likely due to the short time frame between placement and surveying and the small volume of sand placed at R-38. The R-40 profile cross-section comparison (Appendix A) shows a build-out of the berm and beachface at the immediate post-construction survey. It is unlikely that it is due to project spreading as it is not apparent in the R-39 profiles and is not present in the 1-year post-construction survey; however, some of the sand seen at R-40 could be a result of the large quantity of material placed during construction and the movement of the material during construction.

The year-1 post-construction profile at R-39 shows shoreline advancement that is likely due to project spreading but the data do not indicate that spreading occurred further south. The R-39 profile cross-section comparison (Appendix A) shows the build-out of the berm at approximately +9 ft. NGVD and the beachface, which is indicative of project spreading.

The year 2 post-construction profile comparisons indicate a flattening of the beach as the lower beachface builds out (shoreline advancement) with a reduction of the nearshore bar feature at R-39 and R-40. This is likely due to seasonal variation in the profiles.

The year 3 post-construction data also show a reshaping of beach at R-39 and R-40 as the berm became scarped and the sand deposited on the beachface/shoreline area. This shoreline advancement appears to be the natural reshaping of the profiles as the fill from project settles in the profiles.

The remainder of profiles south of the project area do not indicate project spreading in any of the post-construction monitoring years and comparisons of the profile cross-sections show only natural fluctuations in the profile shapes.

Overall, in year 3 post-construction, the shoreline study area south of the project area gained an average of 16 feet from pre-construction conditions.

Beach Profile Volume Quantities

The profile volume is used in this analysis as another indicator of project performance. The volume of each profile was calculated using the USACE software application, BMAP. The volume changes at each profile were calculated by comparing the volume contained in the profiles from the different surveys. The comparisons were made between the landward edge of the constructed beach and MHW and from the MHW to the depth of closure (DOC). The DOC was observed as the depth beyond which no significant change in vertical elevation occurs in successive surveys. A DOC of -18 ft. NGVD for the monitoring period was determined by comparing the pre-construction, post-construction and monitoring surveys to ascertain the seaward limit of significant changes in the elevation when comparing the surveys. It is noted that vertical difference of 0.25 feet in the profile data from the -18 ft. NGVD to -30 ft. NGVD would result in a volume of 244,000 c.y. for the alongshore limits of the monitoring surveys.

Tables 3, 4 and 5 present a summary of the volumetric changes above and below mean high water for the study area by profile when comparing pre-construction data with the immediate post-construction data and the 1-year, 2-year, and 3-year post-construction data. The study area was broken out into three segments in Tables 3 and 4 in order to evaluate project performance: north of the project area, project area, and south of the project area. Note that the weighted averages were calculated using the volumetric change at each profile multiplied by the area of influence of that profile (shoreline length). The weighted average in cubic yards represents the weighted average cubic yards per foot multiplied by the sum of the shoreline length for each segment. Figures 7 and 8 present a graphical comparison of the volumetric changes at each monument in the study area for the above-mentioned comparisons above and below MHW, respectively.

It is also important to note that some of the changes noted in this analysis may be due to seasonal variations in the beach profiles as the pre-construction, immediate post-construction, 1-year post-construction and 2-year post-construction surveys were conducted in the fall (September/October) and winter months (January), and the 3rd year post-construction data were collected in the summer (July). Some of the changes in the beach profile (beyond background erosion/accretion patterns) could be attributable to the seasonal variation of the location of the offshore sandbar which would result in seasonal changes in the volume of material above and below the MHW line. As sand moves between the offshore sandbar and the dry beach, the volume changes above the MHW line and from the MHW line to the DOC will vary seasonally in addition to the background erosion rate and cross-shore adjustment of the constructed profile. Also as previously indicated, the changes in the shoreline position could be attributable to storm-generated swell from tropical storms approaching the southeastern U.S.

Another influence to the beach profile surveys for the monitoring period is the construction of the Jupiter/Carlin Park Shore Protection Project. The renourishment project was completed in March 2002, and the project placed approximately 625,000 cubic yards of sand between R-13 and T-19. Further, in February 2002, the Florida Inland Navigation District placed approximately 120,000 cubic yards of sand dredged from the Jupiter Inlet between the inlet's south jetty and R-14.

North of Project Area

Table 3 and Figure 7 show onshore volumetric loss between the pre-construction survey and the immediate post-construction survey and volumetric gains in all subsequent post-construction surveys. Table 4 and Figure 8 show volumetric gains between MHW and the Depth of Closure (DOC) for all survey comparisons.

Table 3. Volume Changes above Mean High Water

FDEP Reference Monument	Volumetric Changes above MHW (cy/ft)			
	Pre-Construction (2000) to Immediate Post-Construction (2001)	Pre-Construction (2000) to 1-Year Post-Construction (2002)	Pre-Construction (2000) to 2-Year Post-Construction (2003)	Pre-Construction (2000) to 3-Years Post-Construction (summer 2004)
North of Project Area				
T-24	-9.2	10.4	8.9	10.1
T-25	2.5	19.8	17.4	25.6
*** weighted average (cy/ft)**	**-0.6**	**17.3**	**15.1**	**21.4**
*** weighted average (cy)**	**-1,297**	**36,072**	**31,501**	**44,642**
Project Area				
T-26	22.8	32.0	36.4	29.8
T-27	39.8	36.7	37.8	27.0
R-28	43.0	36.2	33.4	21.9
R-29	43.5	44.9	36.4	30.3
R-30	46.0	37.8	38.7	34.6
R-31	39.2	26.1	33.3	22.3
T-32	49.9	29.2	29.0	36.9
R-33	57.9	51.5	50.5	50.5
R-34	50.1	45.4	46.0	43.7
R-35	39.1	35.5	42.7	41.6
R-36	45.4	49.5	48.7	42.3
R-37	44.0	35.4	31.1	31.0
R-38	17.7	22.7	15.0	13.1
*** weighted average (cy/ft)**	**43.2**	**38.0**	**37.8**	**33.7**
*** weighted average (cy)**	**554,042**	**487,551**	**484,350**	**431,845**
South of Project Area				
R-39	5.7	16.4	12.8	13.1
R-40	6.2	3.4	9.2	2.9
R-41	-0.1	-2.8	0.1	-3.2
R-42	1.2	-4.1	1.4	4.9
R-43	5.6	2.1	4.0	2.5
R-44	-1.5	5.6	-0.1	-0.2
*** weighted average (cy/ft)**	**3.5**	**4.4**	**5.7**	**4.6**
*** weighted average (cy)**	**18,986**	**23,697**	**30,761**	**24,774**

Table 4. Volume Changes Below Mean High Water

FDEP Reference Monument	Volumetric Changes between MHW and DOC cy/ft			
	Pre-Construction (2000) to Immediate Post-Construction (January 2001)	Pre-Construction (2000) to 1-Year Post-Construction (2002)	Pre-Construction (2000) to 2-Years Post-Construction (2003)	Pre-Construction (2000) to 3-Years Post-Construction (summer 2004)
North of Project Area				
T-24	35.9	31.0	67.6	32.1
T-25	59.1	49.6	65.4	91.4
*** weighted average (cy/ft)**	**52.9**	**44.7**	**66.0**	**75.5**
*** weighted average (cy)**	**110,330**	**93,124**	**137,624**	**157,502**
Project Area				
T-26	19.2	43.9	54.9	33.2
T-27	84.0	73.8	84.2	49.1
R-28	59.6	77.1	71.3	39.2
R-29	64.3	59.8	79.9	33.6
R-30	72.6	63.6	72.4	49.1
R-31	65.8	43.7	81.4	65.2
T-32	65.4	21.1	51.5	24.2
R-33	49.8	61.0	64.7	28.3
R-34	95.7	92.3	82.5	53.5
R-35	82.2	73.4	115.1	91.7
R-36	118.5	137.8	165.2	126.0
R-37	132.2	99.2	110.3	3.3
R-38	55.1	56.9	54.2	60.6
*** weighted average (cy/ft)**	**78.4**	**72.1**	**87.1**	**51.0**
*** weighted average (cy)**	**1,004,048**	**923,432**	**1,115,950**	**654,171**
South of Project Area				
R-39	5.4	29.3	18.1	37.7
R-40	17.0	14.4	14.8	44.4
R-41	-18.0	15.1	8.5	13.3
R-42	5.3	39.1	24.9	34.1
R-43	2.4	42.4	16.4	26.9
R-44	11.1	48.1	32.4	33.6
*** weighted average (cy/ft)**	**3.7**	**30.3**	**18.2**	**32.3**
*** weighted average (cy)**	**20,073**	**164,404**	**98,688**	**174,849**

Table 5. Summary of Volume Changes

Section	Pre-Construction (2000) to Immediate Post-Construction (January 2001)		Pre-Construction (2000) to 1-Year Post-Construction (2002)		Pre-Construction (2000) to 2-Years Post-Construction (2003)		Pre-Construction (2000) to 3-Years Post-Construction (summer 2004)	
	Above MHW	Below MHW	Above MHW	Below MHW	Above MHW	Below MHW	Above MHW	Below MHW
North of Project Area								
weighted average (cy/ft)	-0.6	52.9	17.3	44.7	15.1	66.0	21.4	75.5
weighted average (cy)	-1,297	110,330	36,072	93,124	31,501	137,624	44,642	157,502
Project Area								
weighted average (cy/ft)	43.2	78.4	38.0	72.1	37.8	87.1	33.7	51.0
weighted average (cy)	554,042	1,004,048	487,551	923,432	484,350	1,115,950	431,845	654,171
South of Project Area								
weighted average (cy/ft)	3.5	3.7	4.4	30.3	5.7	18.2	4.6	32.3
weighted average (cy)	18,986	20,073	23,697	164,404	30,761	98,688	24,774	174,849
Totals								
Project Area (cy)	1,558,090		1,410,982		1,600,300		1,086,016	
Study Area (cy)	1,706,182		1,728,279		1,898,874		1,487,782	

Figure 7
Volume Changes Above MHW Relative to Pre–Construction
Juno Beach Shore Protection Project
2004 Aerial Photography

04–965 Figure 07.dwg Figure 7 4/25/05

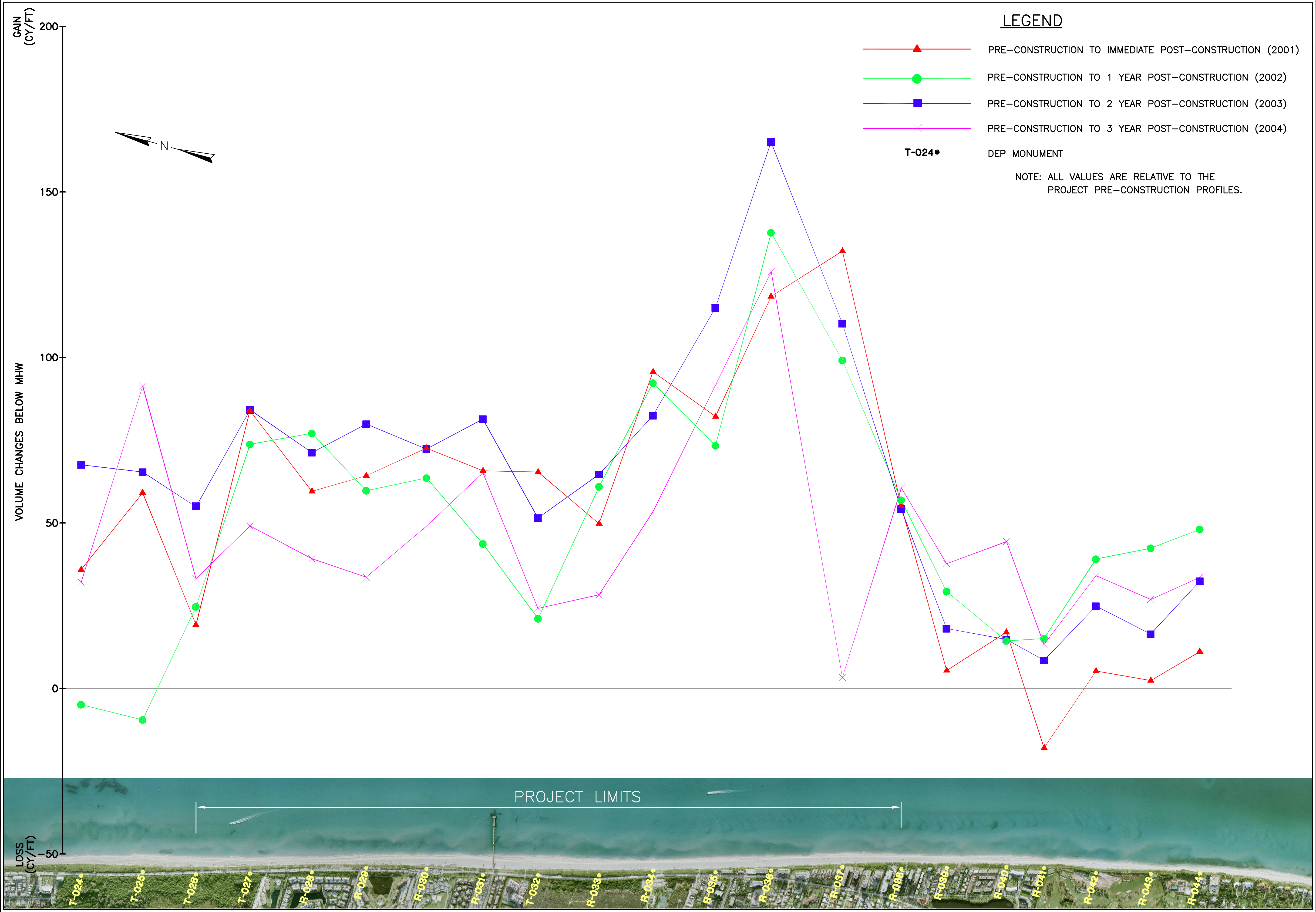

Figure 8
Volume Changes Below MHW Relative to Pre–Construction
Juno Beach Shore Protection Project
2004 Aerial Photography

04-965 Figure 08.dwg Figure 8 4/25/05

Profile cross-sections (Appendix A) show an oddity in the immediate post-construction data at T-24. The runnel in the onshore portion of the beach profile survey of the post-construction survey could be a result of the storms that were experienced during construction, additional material that was placed during construction due to the storm activity, or an anomalous data point. The T-24 and T-25 1-year, 2-year, and 3-year post-construction profiles show a build-out of the beach below the +10 ft. NGVD contour, consistent with what is expected due to project spreading.

Overall, a comparison of the pre-construction survey and the 3-year post-construction survey show volumetric gains onshore (44,650 c.y.) and offshore (157,500 c.y.) that are likely due to project spreading to the updrift beach.

Project Area

The project area includes the shoreline between T-26 and R-38. Tables 3, 4 and 5 show that the project area gained a total of approximately 1,558,000 c.y. above the DOC between the pre-construction survey and the immediate post-construction survey due to the renourishment. A gain of approximately 554,000 c.y. is observed above MHW and approximately 1,004,000 c.y. below MHW. This value differs from the pay volume of 1,043,000 c.y. of sand that was placed on the beach for the project, however, comparison and analysis of subsequent surveys supports this increased value of sand placement. This measured value implies a realized placement that is approximately 50 percent higher than the reported placed value. County staff has indicated that during construction, the contractor often had to re-fill acceptance sections due to weather and equipment downtime.

Table 3, Figure 7, and comparison of the profile cross-sections (Appendix A) show a steady loss of sand from above MHW over the 3-year monitoring period. These losses are consistent with project equilibration, with large losses seen in the first year of post-construction monitoring, and a steady reduction of the beachfill in subsequent years.

Above MHW, the 1-year post-construction survey shows an increase in volume at the ends of the project and a reduction in the volume throughout the remainder of the project area. This trend is consistent with project equilibration as the sand is naturally redistributed along the beach and spreads to the adjacent beaches. The 2nd year post-construction survey data depict some unexpected results with slight volumetric gains in the beach above MHW in most of the project area and slight volumetric losses in the beach in the very southern portion of the project area. These gains could be attributable to the effects of the Jupiter/Carlin Park project, seasonal swell due to tropical activity, or as a result of the fact that the contractor had to place additional sand in acceptance sections due to direct weather activity. The 3rd year post-construction survey data return to the expected trend of volumetric losses above MHW in the project area.

Between MHW and the DOC, Table 4, Figure 8, and Appendix A also show some unexpected volumetric changes. A comparison of the immediate post-construction and the 1st year post-construction survey data indicates a volumetric loss. Typically, volumetric gains are observed as the beachfill that is placed on the beach equilibrates into the nearshore area. Volumetric increases are seen below MHW in the 2nd year post-construction survey data. The presence of the pier in the vicinity of R-31 can result in shoreline advancement and volumetric accretion within the vicinity of the pier; however, the presence of the pier would not result in some of the anomalies observed in the survey data. The margins of potential error in the survey data, as described in previous sections, should be kept in mind in assessing the survey data. The typical signature of a pier in the monitoring data would be a reasonable amount of shoreline and volumetric accretion in the shorelines immediately adjacent to the pier. It is likely that the pier is trapping a certain amount of sand, but it is also evident that there are possible anomalies in the monitoring data. The anomalies could be a result of Jupiter/Carlin Park project, the Florida Inland Navigation District project, the amount of material placed for this renourishment, or natural variations in the shoreline. The 3rd year post-construction survey data return to the anticipated trend of volumetric losses below MHW in the project area.

At the 3rd year post-construction survey, the profile data show that the project area contains a total of approximately 1,086,000 c.y. (or approximately 70 percent) of sand from the renourishment project as measured at the immediate post-construction survey. Approximately 431,850 c.y. remains above MHW and approximately 654,170 c.y. remains below MHW when compared to pre-project conditions.

Profile cross-sections in Appendix A show the shifting of the nearshore sand bar feature that is present throughout the project area and the changing shapes of the profiles that occur during equilibration and due to the changing seasons of data collection. Overall, the cross-sections show how well the beach template has retained sand in the project area.

South of the Project Area

The area immediately to the south of the project area between R-39 and R-44 was also evaluated for volumetric changes.

Table 3 and Figure 7 show overall onshore volumetric gains between the pre-construction survey and the immediate post-construction survey and in all subsequent post-construction surveys. Table 4 and Figure 8 also show overall volumetric gains between MHW and the Depth of Closure (DOC) for all survey comparisons.

Above MHW, the small volumetric gains noted between pre-construction and immediate post-construction at R-39 and R-40 are possibly due to project spreading. The gains seen in subsequent surveys are likely due to project spreading as the gains at R-39 are significantly higher than gains to the south as would be expected with longshore spreading. The higher than expected volumetric gains could be a result of the additional placed material during construction and project spreading during construction due to the weather that was experienced. However, the spreading seems to be limited to the R-39 and R-40 area as volumetric losses are noted to the south in most of the post-construction surveys.

Below MHW, a similar trend of volumetric gains at R-39 and R-40 is observed except in year 3 in which a larger volumetric gain is noted at R-40 than at R-39. The reason for this is unknown. Additionally, volumetric gains are observed further south than were realized above MHW.

Profile cross-sections depict shoreline advances at R-39 and R-40 that mimic the shoreline advances due to beachfill placement, and thus, volumetric gains are attributed to project spreading. Changes at R-41 through R-44 appear to be natural fluctuations in the profiles. Note the shifting sand bar feature in all profiles.

Overall, a comparison of the pre-construction survey and the 3-year post-construction survey show volumetric gains onshore (24,800 c.y.) and offshore (174,850 c.y.) that are likely due to project spreading to the downdrift beach.

Equilibrium Toe of Fill (ETOF) and Hardbottom Evaluation

A region of historic hardbottom is located in the nearshore of Juno Beach between approximately R-28 and R-31. This feature is ephemeral in nature as indicated by the figures in Appendix B. These figures compare the exposed nearshore hardbottom in the region in 1985, 1991, 1992, 1993, 1994, January 1997, August 1997, and May 1998. Although, the hardbottom in the vicinity of R-28 through R-31 does not have a consistent boundary delineation, a central portion of the hardbottom appears to be persistent, which could be indicative of a higher relief feature. The adjacent hardbottom is likely to be low-relief, and it does appear to be ephemeral. The acreages of exposed hardbottom as documented for these surveys by Palm Beach County are shown in Table 6. The project area limits are R-26 through R-38; the study area limits are R-24 through R-44.

As part of this analysis, the location and extent of hardbottom prior to nourishment and post-construction was evaluated and compared in order to determine any adverse impacts of the nourishment project.

The time average amount of exposed hardbottom in the project area was 3.77 acres (between February 1985 and May 1998). To mitigate for burial of this hardbottom, an artificial reef was constructed offshore of R-23, 24, and 25. Approximately 4 acres (as reported by Palm Beach County) of mitigation were required to mitigate for the project's impacts. In 2001 and 2003 there were 3.00 and 2.82 acres exposed, respectively, of the mitigation reef constructed thus far. This reef can be clearly seen in the 2004 aerial photographs of the study area.

Figures 9 and 10 show a comparison of the exposed hardbottom, as delineated by Palm Beach County, for May 1998 and 2001, and 2001 and 2003. All hardbottom delineation is presented overlaid on 2004 aerials. The May 1998 (pre-construction) data documented that 2.67 acres of hardbottom was exposed in the nearshore between R-28 and R-31 (Figure 9a). In 2001 (6-months post-construction), none of this hardbottom was exposed within the fill limits (Figure 9b). This feature is not present in any previous study nor is it present in the 2003 delineation or the 2004 aerials.

Table 6. Historically Time-Averaged Exposure of Hardbottom as Delineated by Palm Beach County.

Survey (Date of Aerial Photography)	Duration of Exposure (days)	**Project Area (Direct Impacts)**			**Adjacent Area (Indirect Impacts)**			**Survey Area**		
		Exposed Hardbottom (acres)	Ave. Exposure (acres)	Ave. Exposure (acres-days)	Exposed Hardbottom (acres)	Ave. Exposure (acres)	Ave. Exposure (acres-days)	Exposed Hardbottom (acres)	Ave. Exposure (acres)	Ave. Exposure (acres-days)
Feb 16, 1985		2.35			0.88			3.23		
	2,373		2.37	5,624		3.61	8,555		5.98	14,179
Aug 17, 1991		2.39			6.33			8.72		
	369		3.18	1,172		4.56	1,683		7.74	2,854
Aug 20, 1992		3.96			2.79			6.75		
	337		2.85	959		2.65	894		5.50	1,853
Jul 23, 1993		1.73			2.52			4.25		
	382		2.32	886		2.37	906		4.69	1,793
Aug 9, 1994		2.91			2.23			5.14		
	879		6.64	5,832		2.23	1,960		8.87	7,792
Jan 4, 1997		10.36			2.23			12.59		
	213		9.86	2,100		1.91	407		11.77	2,507
Aug 5, 1997		9.36			1.59			10.95		
	271		6.02	1,630		2.38	644		8.39	2,274
May 3, 1998		2.67			3.16			5.83		
Total	4,824			18,203			15,048			33,251
Time Averaged		**3.77**			**3.12**			**6.89**		

In 2003 (2-years post-construction), the data indicate that no hardbottom was exposed within the project limits (Figures 10a and 10b). And although a detailed analysis of the hardbottom based on 2004 data have not been completed, the 2004 aerial images (3-years post-construction) do not show any exposed hardbottom within the project limits. Table 7 depicts the exposed hardbottom as delineated by Palm Beach County for the pre- and post-construction available data as presented in Figures 9 and 10.

Table 7. Exposed Hardbottom as delineated by Palm Beach County Pre- and Post-Project[1]

Survey	Exposed Hardbottom in Project Area (acres)	Exposed Hardbottom in Study Area (acres)	Exposed Hardbottom – Total (acres)	Mitigation Reef (acres)
May 1998	2.67	3.16	5.83	0
2001	0.00	2.22[2]	2.22[2]	3.00
2003	0.00	2.12[3]	2.12[3]	2.82
2004	0.00	Not Yet Available	Not Yet Available	Not Yet Available

Notes: 1) The hardbottom mapping delineations were provided by Palm Beach County Department of Environmental Resource Management staff.
2) This value includes 2.18 acres of the mitigation reef in the vicinity of R-24 within the study limits.
3) This value includes 1.95 acres of the mitigation reef in the vicinity of R-24 within the study limits.

In the southern portion of the study area downdrift of the project area, between R-38 and R-44, the hardbottom is generally ephemeral in nature. From 1998 to 2001, the hardbottom between R-38 and R-44 location changes drastically, with a very small amount of persistent hardbottom between R-43 and R-44. From 2001 to 2003, the amount and location of exposed hardbottom between R-38 and R-44 is not consistent. As seen in Appendix B, this area is very close to the shoreline and is routinely covered and uncovered naturally, with the exception of an area between R-41 and R-42 that is generally persistently exposed. The profile cross-sections for this area indicate that the hardbottom in this area has not been affected by the project.

The equilibrium toe of fill (ETOF) was identified from a comparison of the pre-construction survey data (2000) and the 1-year post-construction data (October 2002). The ETOF is identified as the offshore location where the 2000 and 2002 beach profile surveys converge. The location of ETOF at each FDEP Reference Monument is plotted on the aerials in Figure 11 and the distance from each monument to the ETOF is presented in Table 8. Figure 11 depicts the 1998 hardbottom delineation as well as the 2003 hardbottom and the 2002 ETOF overlaid on the 2004 aerials. The figure shows that the pre-construction hardbottom (1998)

04-965 Figure 09.dwg Figure 9a 5/2/05

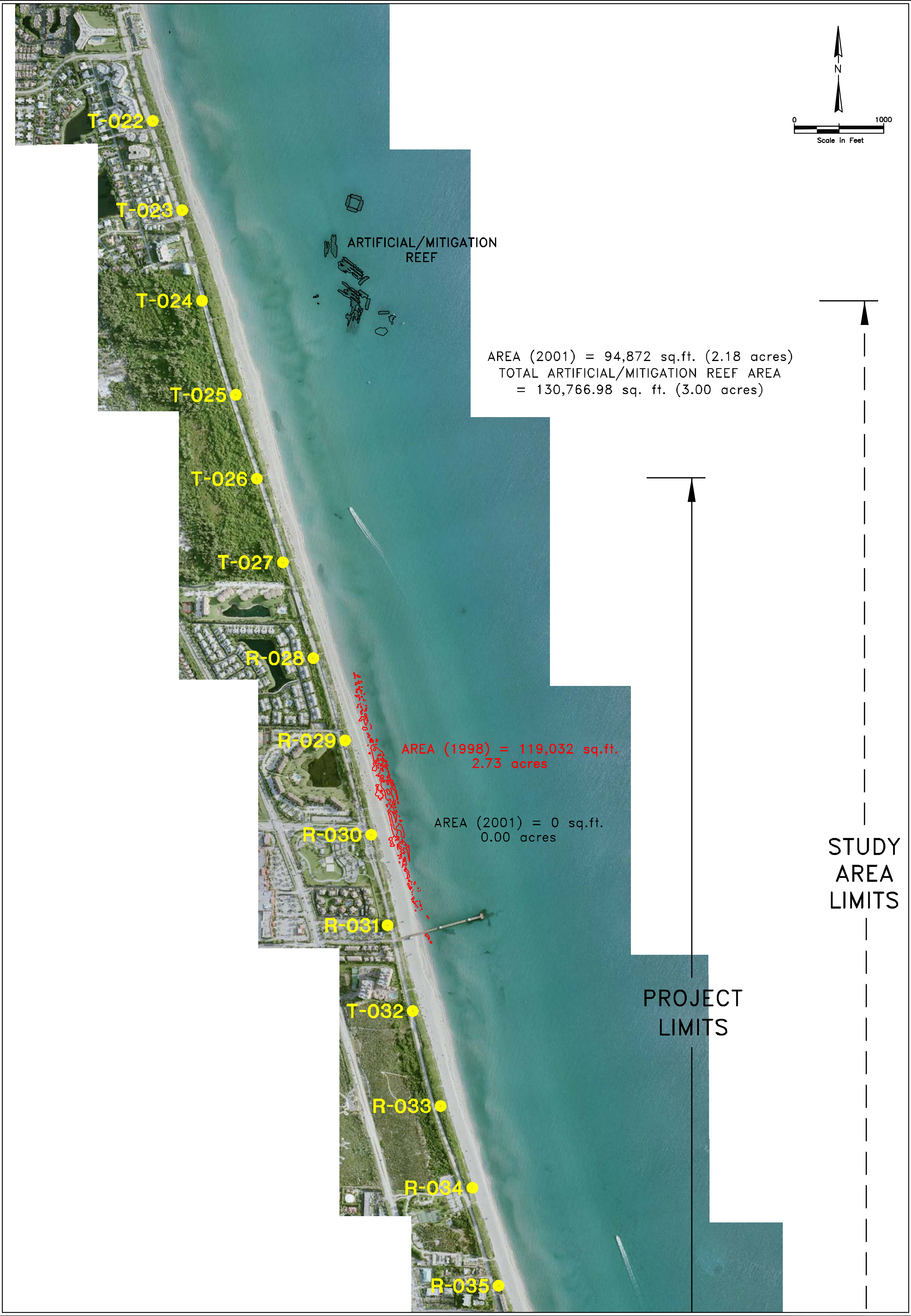

Figure 9a
Nearshore Hardbottom Comparison of Pre-Construction (1998) and Immediate Post-Construction (2001) Surveys
Juno Beach Shore Protection Project
2004 Aerial Photography

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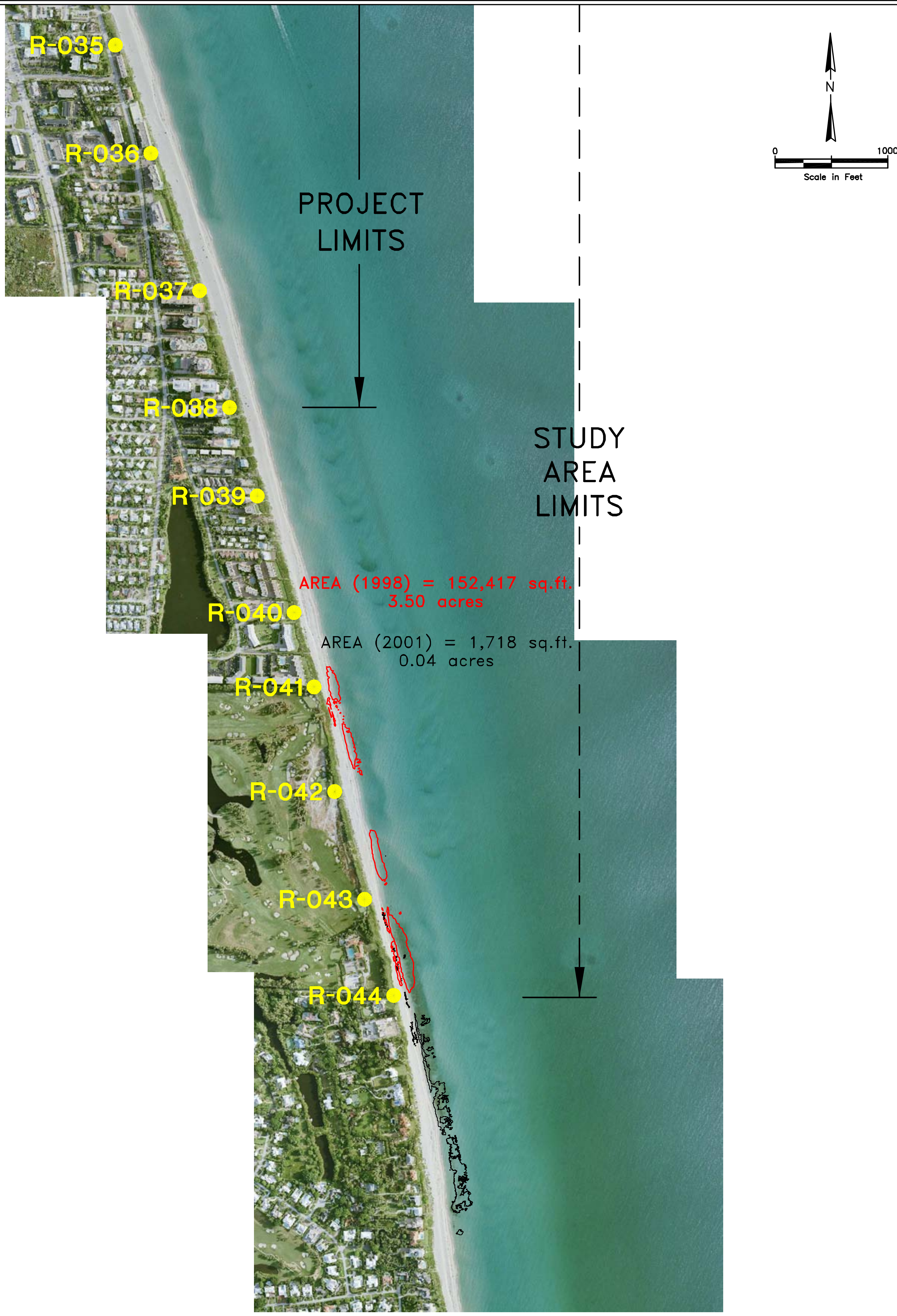


MAY 1998 NEARSHORE HARDBOTTOM TOTAL
FILL AND STUDY AREA= 271,449 sq.ft. (6.23 acres)

2001 NEARSHORE HARDBOTTOM TOTAL
FILL AND STUDY AREA= 96,590 sq.ft. *2.22 acres
*INCLUDES 2.18 ACRES OF THE ARTIFICIAL REEF
TOTAL ARTIFICIAL/MITIGATION REEF AREA
= 130,766.98 sq. ft. (3.00 acres)

Figure 9b
Nearshore Hardbottom Comparison of Pre-Construction (1998) and Immediate Post-Construction (2001) Surveys
Juno Beach Shore Protection Project
2004 Aerial Photography

ATM APPLIED TECHNOLOGY & MANAGEMENT, INC

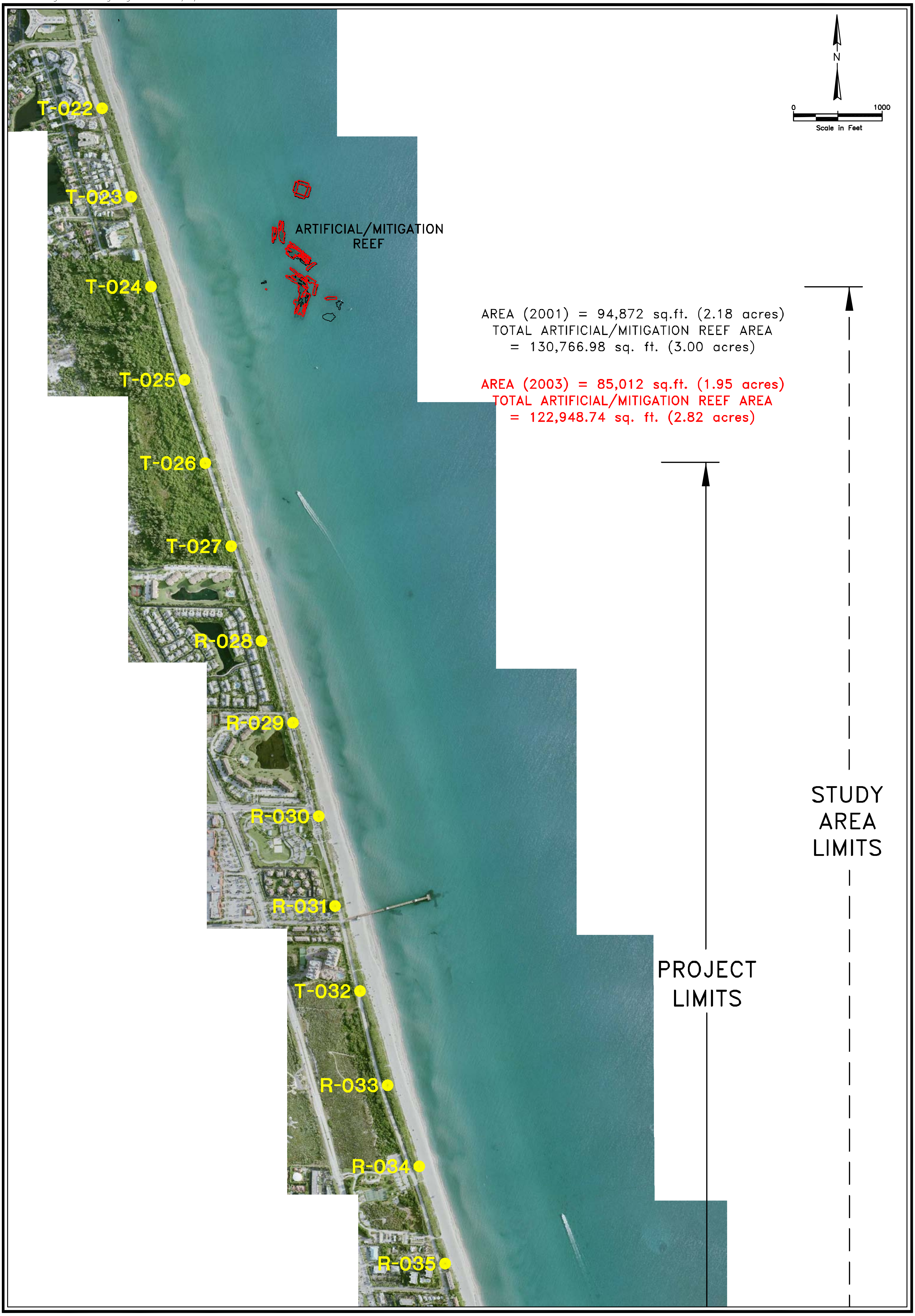
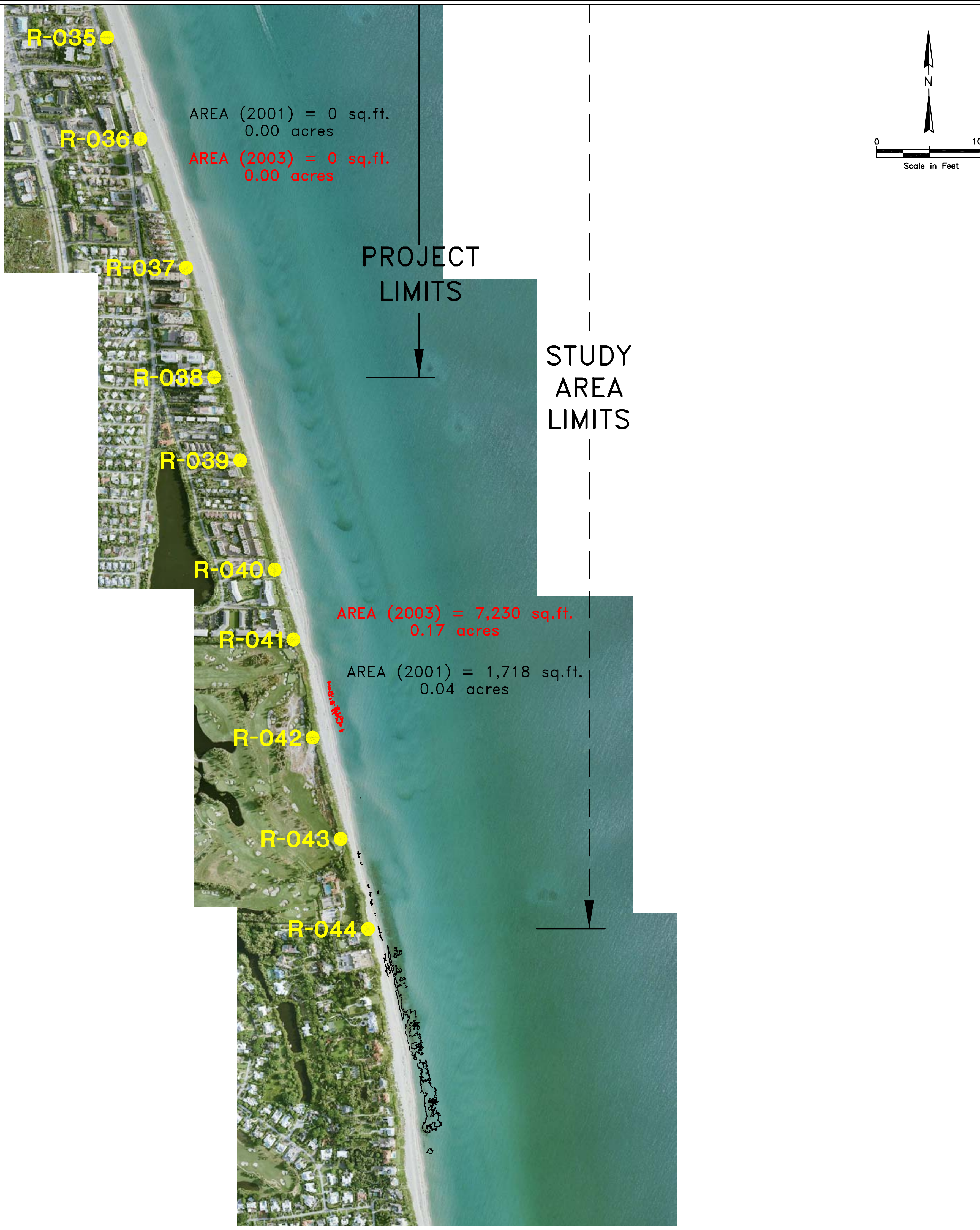


Figure 10a
Nearshore Hardbottom Comparison of the Immediate Post-Construction (2001) and Two-Year Post-Construction (2003) Surveys
Juno Beach Shore Protection Project
2004 Aerial Photography

APPLIED TECHNOLOGY & MANAGEMENT, INC



<u>2001 NEARSHORE HARDBOTTOM TOTAL</u>
FILL AND STUDY AREA= 96,590 sq.ft. *2.22 acres
*INCLUDES 2.18 ACRES OF THE ARTIFICIAL REEF
TOTAL ARTIFICIAL/MITIGATION REEF AREA
= 130,766.98 sq. ft. (3.00 acres)

<u>2003 NEARSHORE HARDBOTTOM TOTAL</u>
FILL AND STUDY AREA= 92,242 sq.ft. *2.12 acres
*INCLUDES 1.95 ACRES OF THE ARTIFICIAL REEF
TOTAL ARTIFICIAL/MITIGATION REEF AREA
= 122,948.74 sq. ft. (2.82 acres)

Figure 10b
Nearshore Hardbottom Comparison of the Immediate Post-Construction (2001) and Two-Year Post-Construction (2003) Surveys
Juno Beach Shore Protection Project
2004 Aerial Photography

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Figure 11
2002 Equilibrium Toe of Fill Locations
Juno Beach Shore Protection Project
2004 Aerial Photography

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BEACHFILL DIFFUSION

Figure 12 presents the diffusion of the beachfill following the nourishment project. The figure indicates the remaining fill volume as measured above the -18 ft. NGVD contour. The amount of material remaining within the project limits is based on a post-construction volume of 1,558,000 cubic yards (Table 5). Table 9 presents the amount of material remaining in the project area and the study area relative to the post-construction volume as surveyed within the limits of the project area.

Table 9. Percent of Remaining Material.

Monitoring Period (Year of Monitoring Survey)	Fraction of Material	
	Within Project Area	Within Study Area
Post-Construction – (2001)	100%	110%
1-Year (2002)	91%	111%
2-Year (2003)	103%	122%
3-Year (2004)	70%	95%

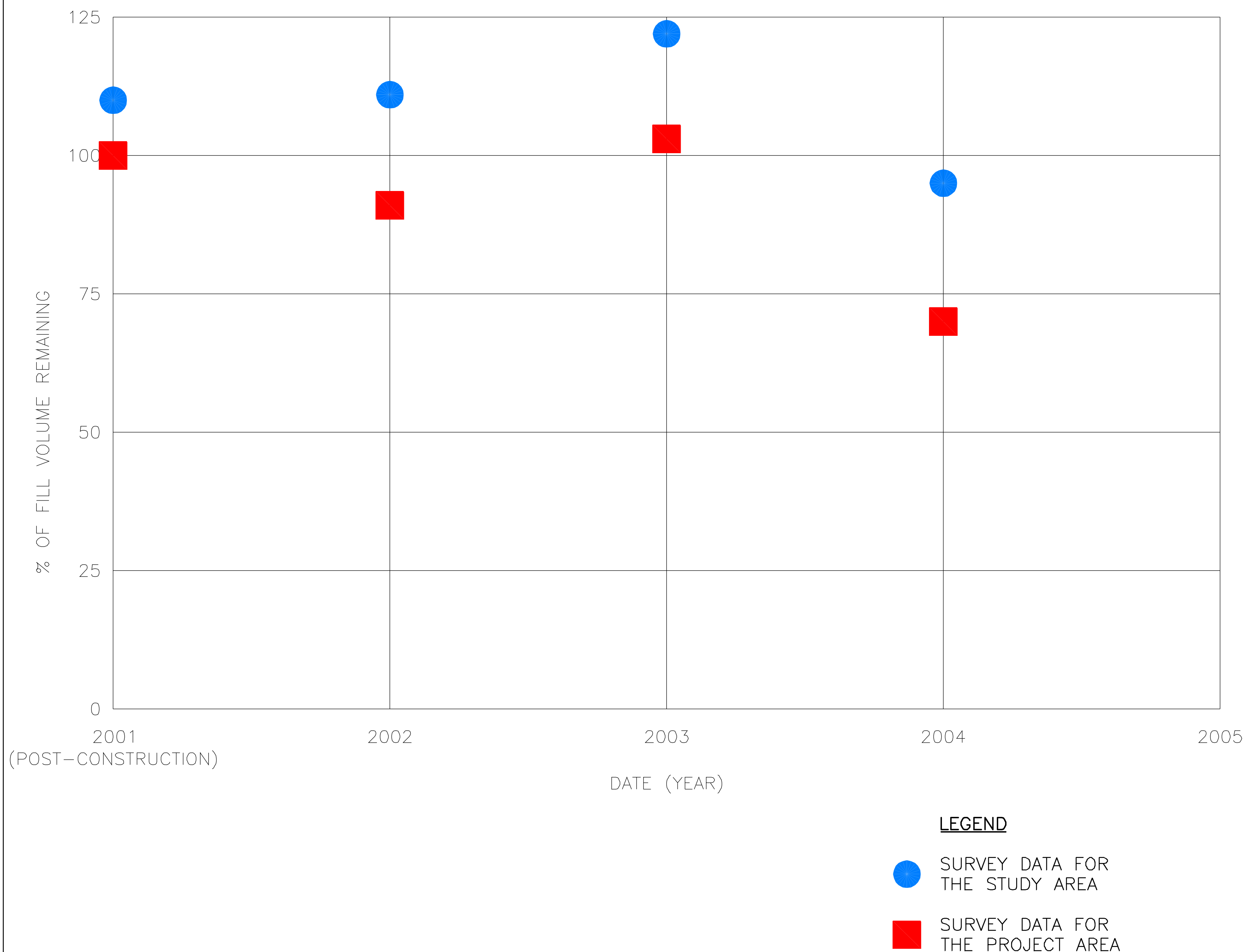
The beachfill project shows the expected trend of declining beachfill remaining as the project fill spreads to adjacent beaches over time. However, the 2-year post-construction data indicate a volume increase in the project area that was not anticipated. Profile cross-section comparisons and the beachfill volume analysis indicate a gain in material below MHW. The amount of volume in the project area for 2002 could be anomalous (Figure 12) due to the construction of the Jupiter/Carlin Park project, placement of dredged material by the Florida Inland Navigation District, the amount of material placed for this renourishment, and natural variations in the shoreline. As described in previous sections, the margins of potential error in the survey data should be kept in mind in assessing the survey data. The typical signature of a pier in the monitoring data would be a reasonable amount of shoreline and volumetric accretion in the shorelines immediately adjacent to the pier. It is likely that the pier is trapping a certain amount of sand, but its effect on project spreading is likely to be insignificant.

CONCLUSIONS

Subsequent to acquisition and analysis of pre-construction, immediate post-construction, 1-year, 2-year, and 3-year post-construction surveys of the project and study areas, the following observations are offered:

- The average increase in shoreline width in the project area at the time of the 3-year post-construction survey was approximately 108 feet compared to pre-project shoreline;

Figure 12
Beachfill Diffusion Analysis
Juno Beach Shore Protection Project



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- In the first 3 years following project construction, the project area shows that approximately 70 percent of the renourishment project volume (measured at immediate post-construction) remained within the project area above the -18 ft. NGVD contour and 95 percent of this sand remained within the study area;

- Moderate project spreading was observed updrift of the project area with increases in the beach and nearshore areas and minor project spreading was observed downdrift of the project area. The updrift beach shows an average shoreline advance of 86 feet between pre-construction and 3-years post-construction. The downdrift shoreline indicates an average advancement of 16 feet between pre-construction and 3-years post-construction. The project spreading to the north could be influenced by the March 2002 renourishment of the Jupiter /Carlin Park Shore Protection Project;

- All of the hardbottom as documented as exposed in 1998 within the project area is within the equilibrium toe of fill and was covered by the beachfill project. Hardbottom analysis in 2004 indicates that none of this hardbottom has been re-exposed;

- Within the project limits, no additional hardbottom was covered due to the nourishment project. As of 2003, 2.12 acres of hardbottom are exposed within the study area as compared to 5.83 acres of exposed hardbottom in May 1998 prior to the project. The hardbottom in the southern region of the study area is generally ephemeral with some areas of persistent exposure;

- In 2001, there were 3.00 acres of mitigation reef, and in 2003, there were 2.82 acres of mitigation reef.

- It is important to note that a comparison of the pre-construction and immediate post-construction surveys indicates that approximately 1,558,000 c.y. of sand were placed between the dune and the DOC for the beach nourishment. A gain of approximately 554,000 c.y. is observed above MHW and approximately 1,004,000 c.y. below MHW. This value differs from the reported pay volume of 1,043,000 c.y.; however, comparison and analysis of subsequent surveys supports this increased value of sand placement. The pay volume is lower than the surveyed volume due to the fact that the contractor had to re-pump sand into acceptance sections as a result of downtime due to storms and mechanical problems; and,

  A comparison of the data with the pre-construction survey data and immediately post-construction data indicate that more sand is present during the 2nd year post-construction survey than expected. Slight volumetric gains are observed in the beach above MHW in most of the project area between the 1-year post-construction data and the 2-year post-construction data. These gains are likely due to potential margins of error in the surveys, the construction of the Jupiter/Carlin Park renourishment project, or placement of material updrift of the project by the

Florida Navigation District, seasonal variations in the width of the dry beach, or the effects of storm swell due to tropical storm activity. The expected trends of project equilibration and spreading are observed in year 1 and year 3 post-construction.

RECOMMENDATIONS

The following are offered for consideration by Palm Beach County and FDEP:

- Continue the project performance monitoring of the study area, at a minimum, through the FDEP permit-required monitoring period;

- Analysis of post-hurricane beach conditions to determine project performance and remaining fill volume; and,

- Monitor the amount of placed material remaining within the project limits and the effect, if any, of storm activity on the renourishment schedule.

Appendix A – Juno Beach Shore Protection Project
Beach Profile Comparison Plots

04-965 Appendix A - Cross Sections.dwg T-24 4/27/05

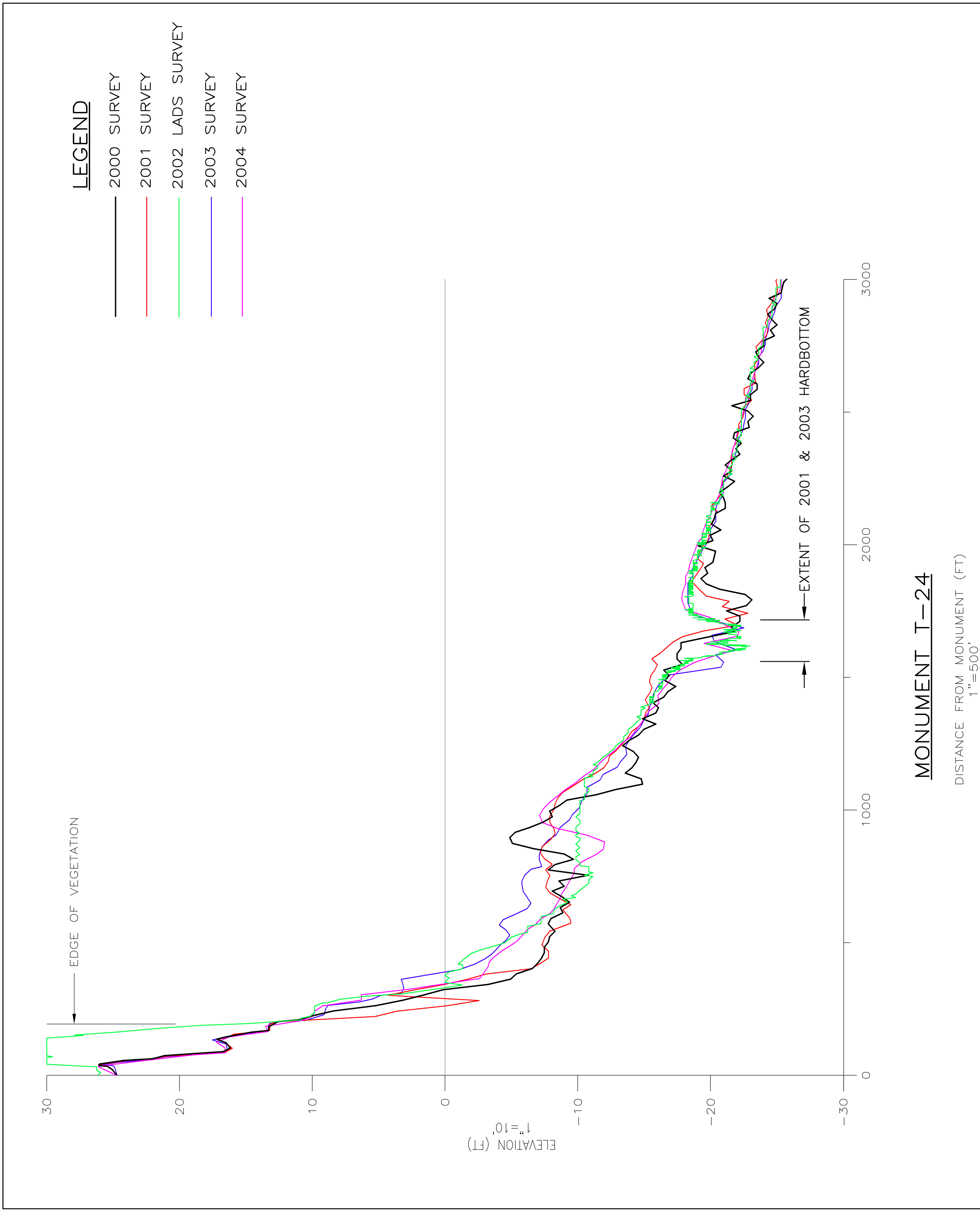

Figure A-1
Beach Profile Comparison at Monument T-24
Juno Beach Shore Protection Project

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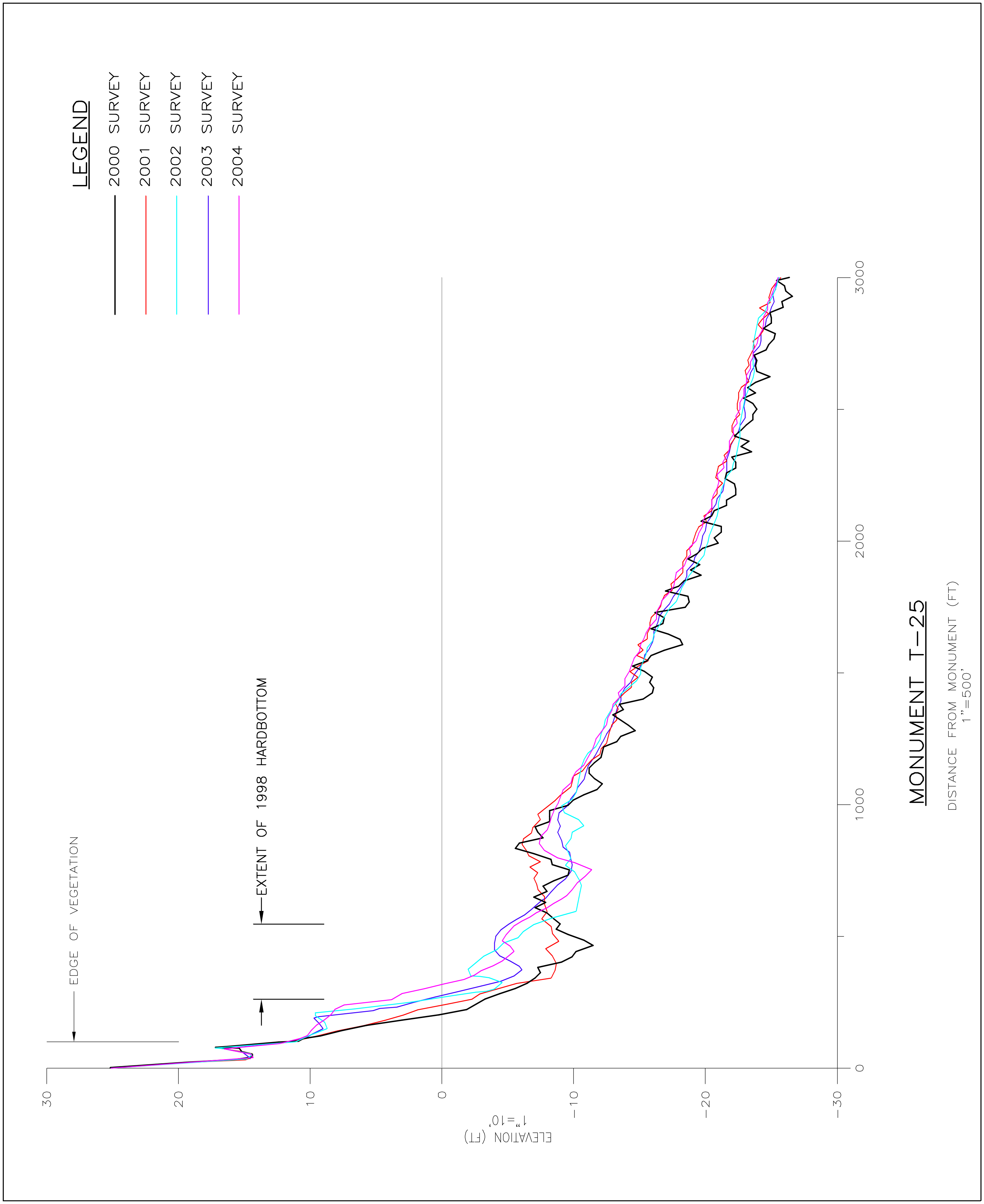

04-965 Appendix A - Cross Sections.dwg T-25 4/26/05

Figure A-2
Beach Profile Comparison at Monument T-25
Juno Beach Shore Protection Project

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04-965 Appendix A - Cross Sections.dwg T-26 4/26/05

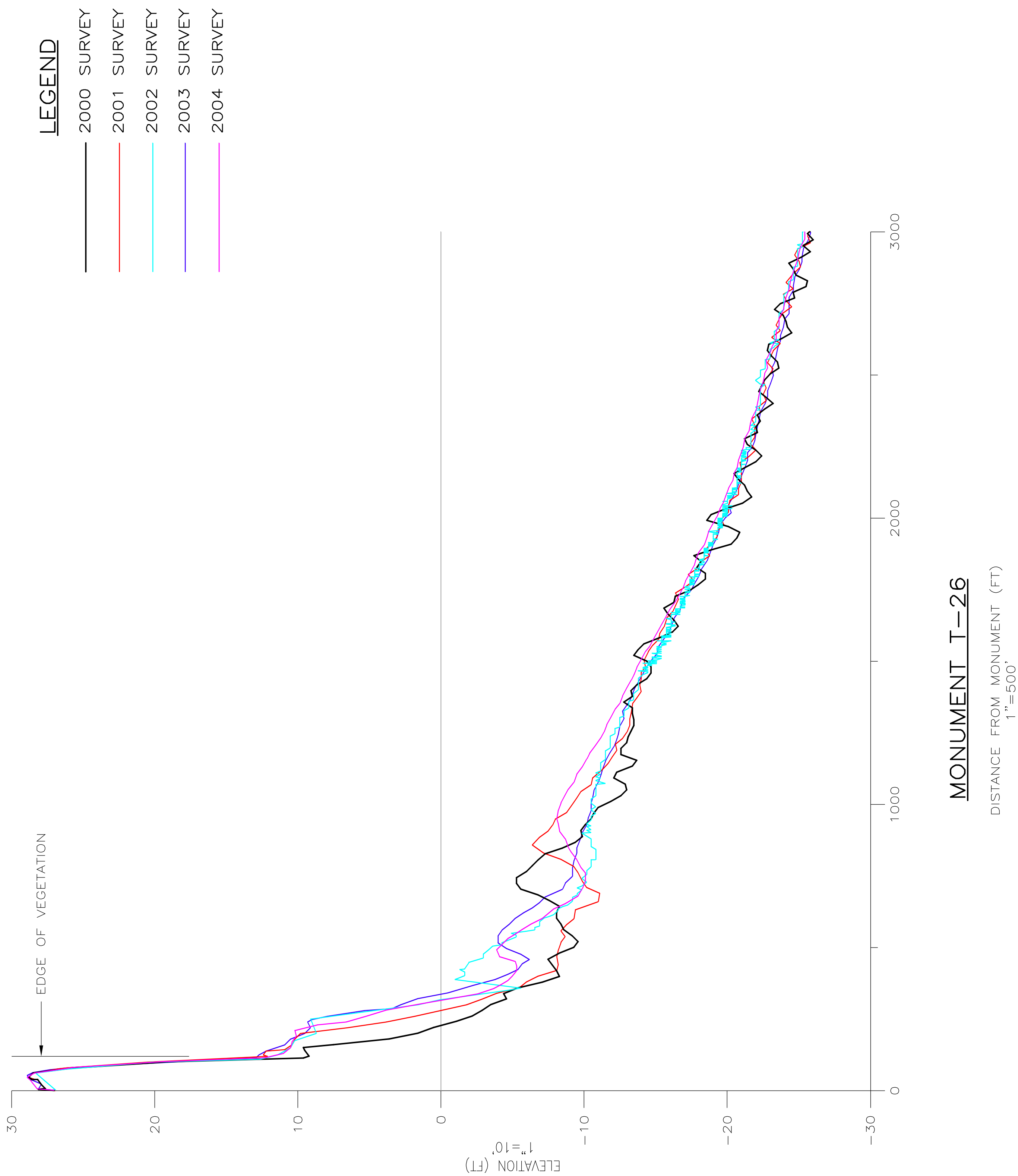

Figure A-3
Beach Profile Comparison at Monument T-26
Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC

04-965 Appendix A - Cross Sections.dwg T-27 4/26/05

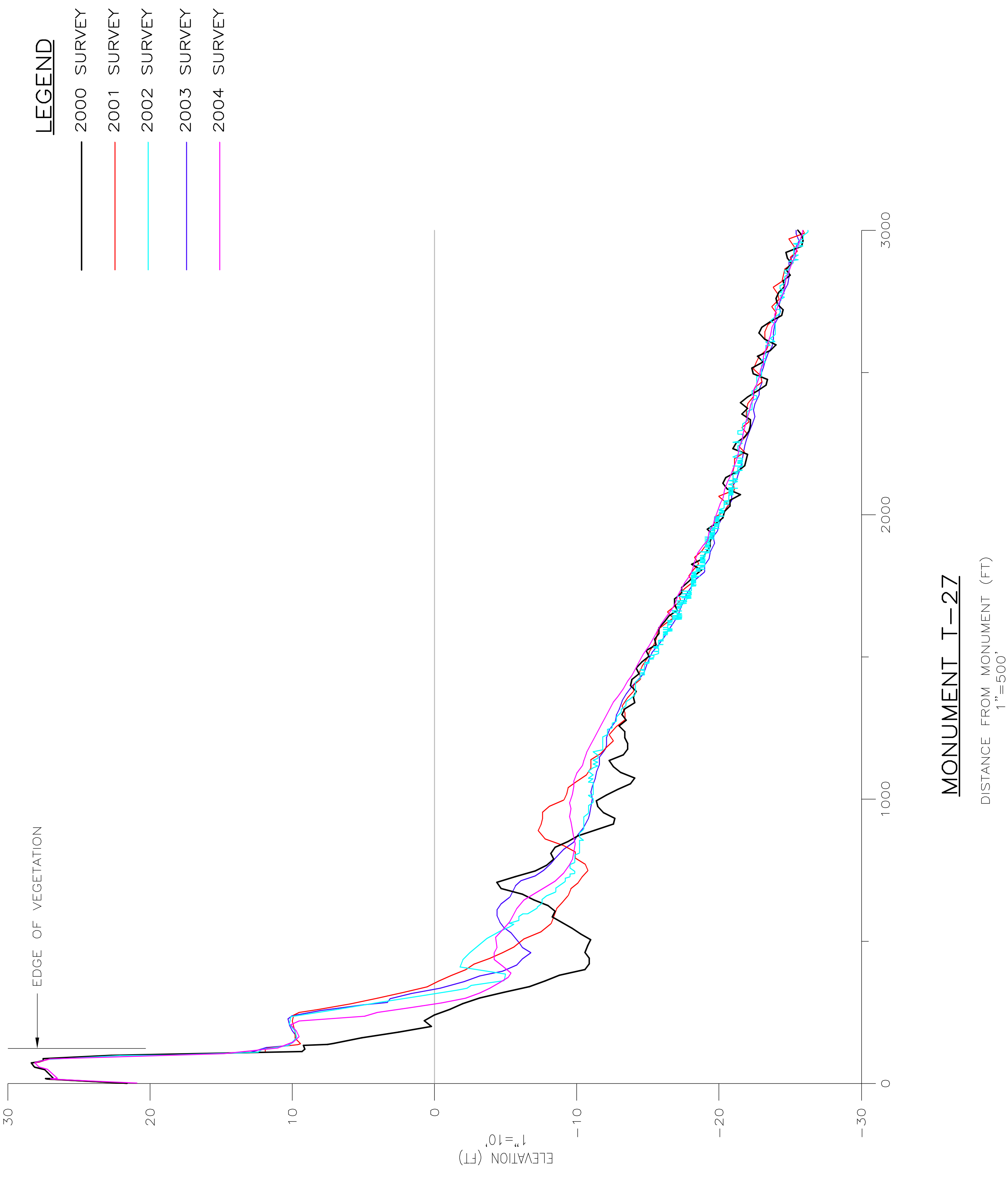

Figure A-4
Beach Profile Comparison at Monument T-27
Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC

04-965 Appendix A - Cross Sections.dwg R-28 4/26/05

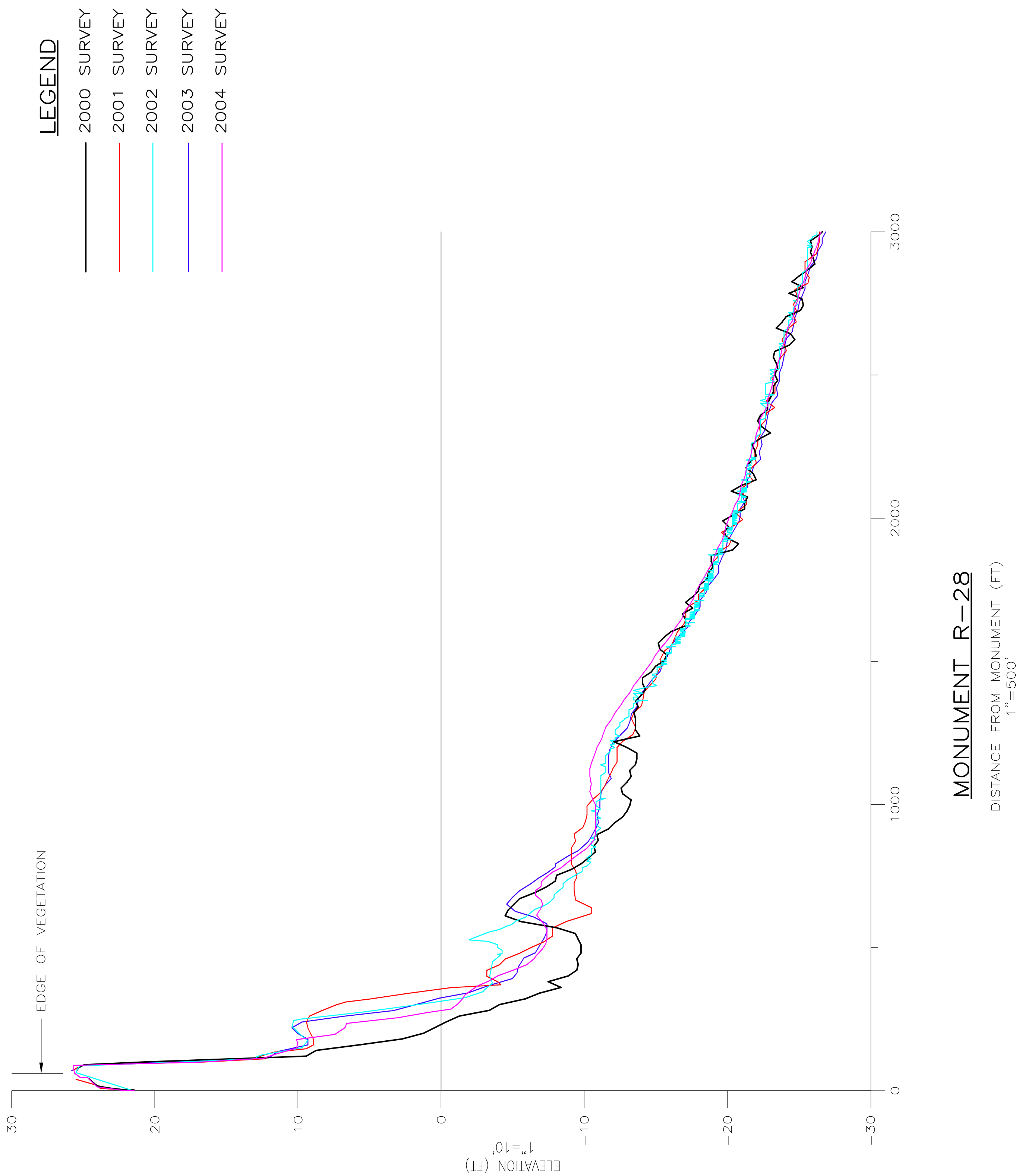

Figure A-5
Beach Profile Comparison at Monument R-28
Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC

04-965 Appendix A - Cross Sections.dwg R-29 4/27/05

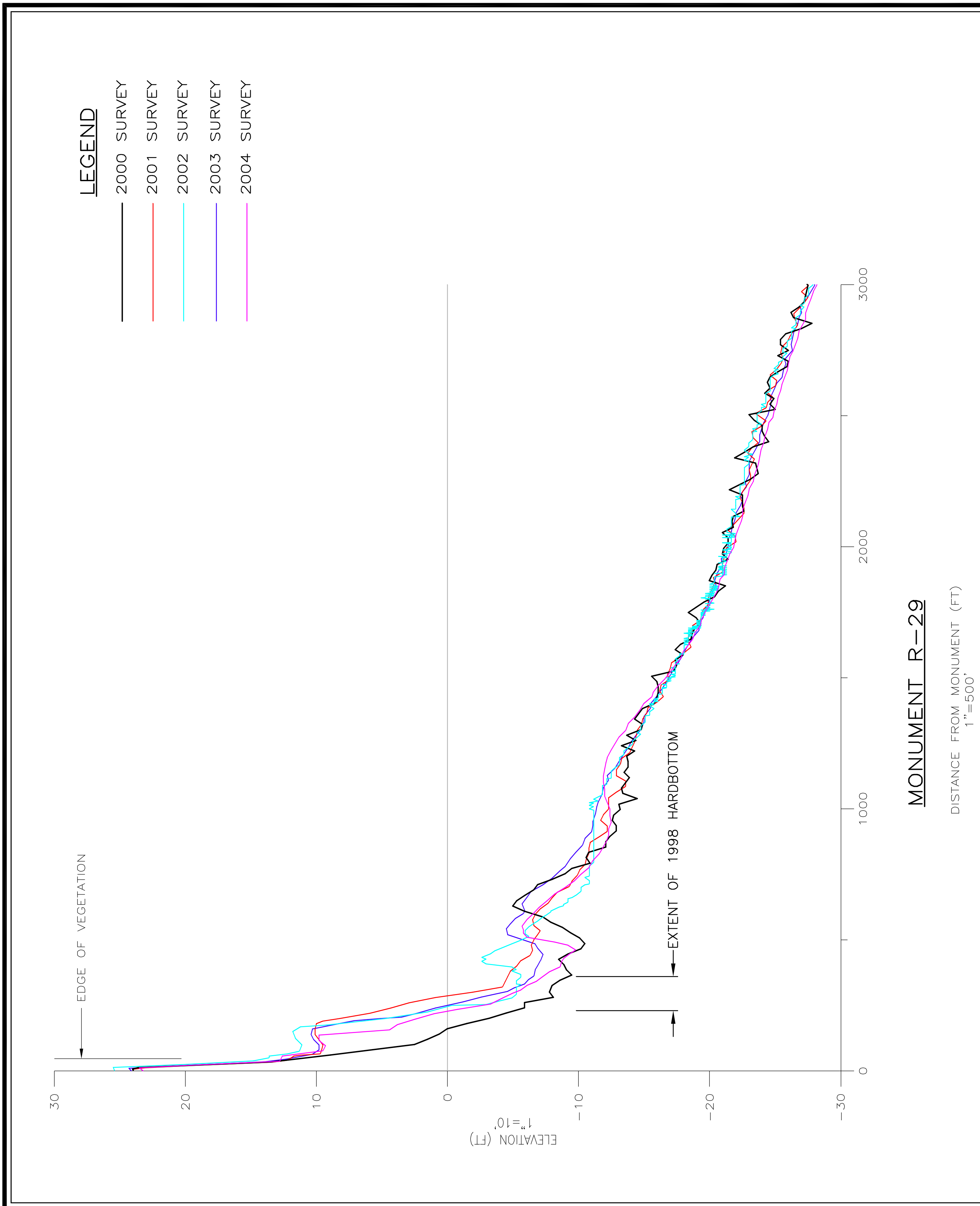

Figure A-6
Beach Profile Comparison at Monument R-29
Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC

04-965 Appendix A - Cross Sections.dwg R-30 4/27/05

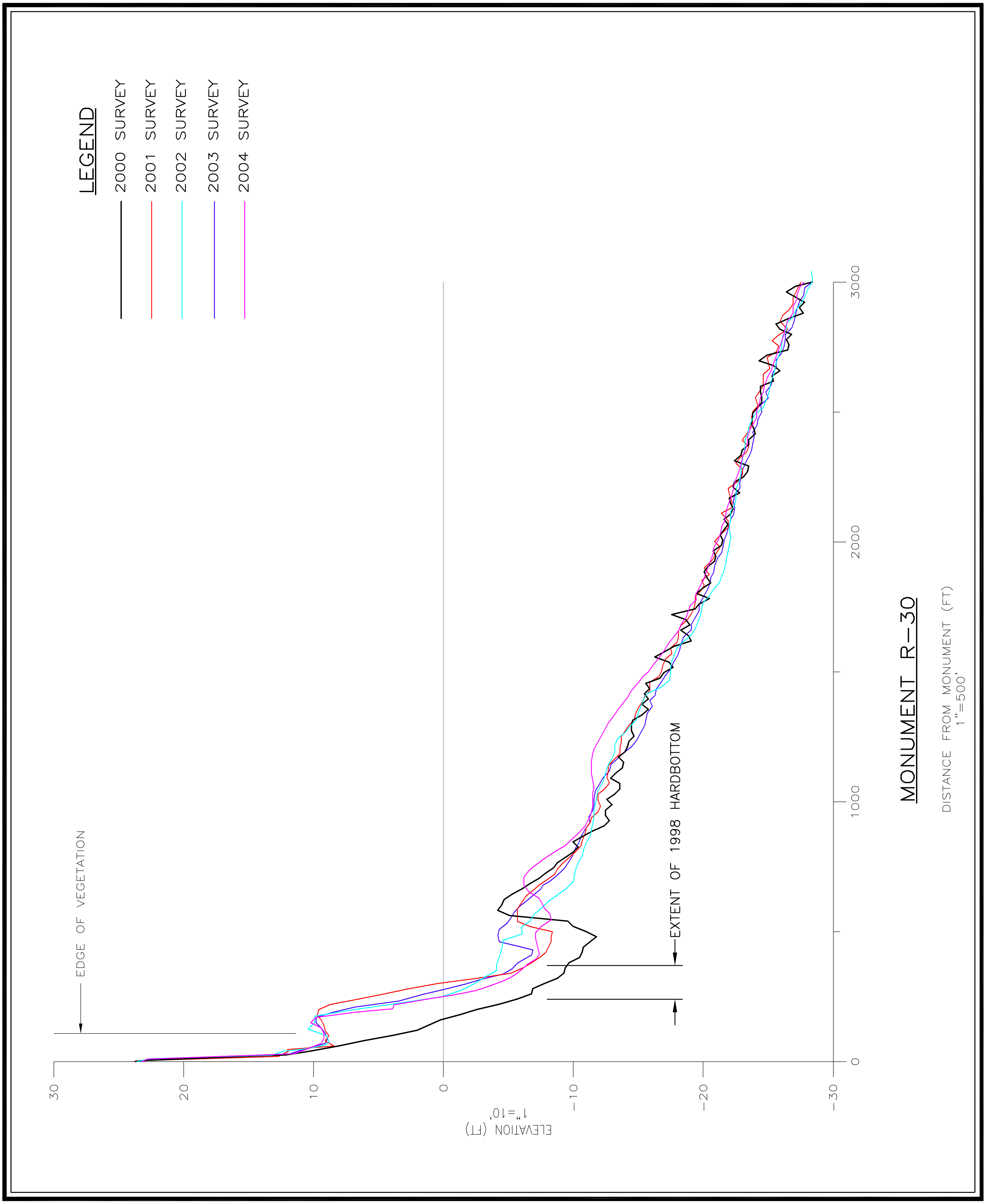

Figure A-7
Beach Profile Comparison at Monument R-30
Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC

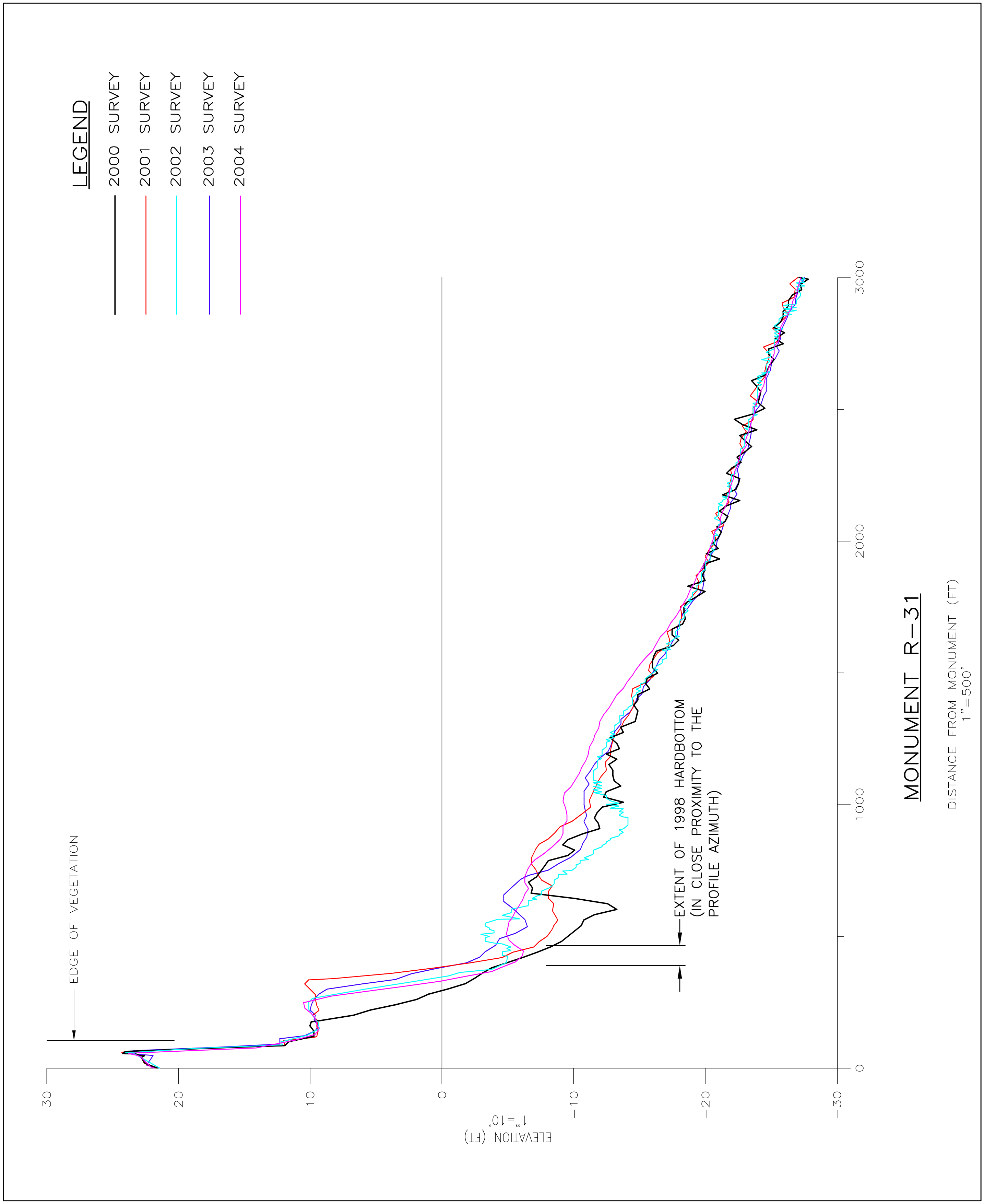

Figure A-8
Beach Profile Comparison at Monument R-31
Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC

04-965 Appendix A - Cross Sections.dwg T-32 4/26/05

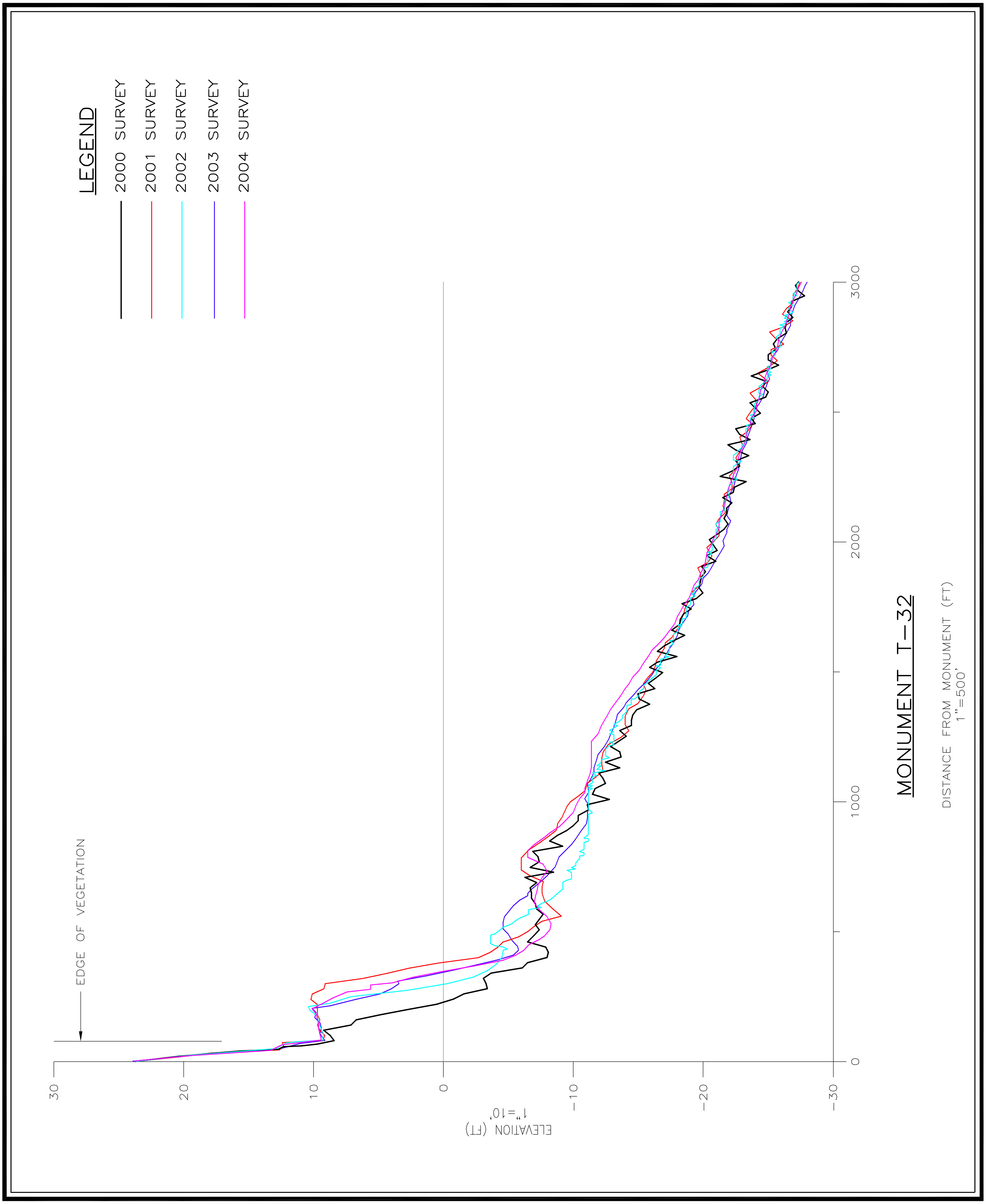

Figure A-9
Beach Profile Comparison at Monument T-32
Juno Beach Shore Protection Project

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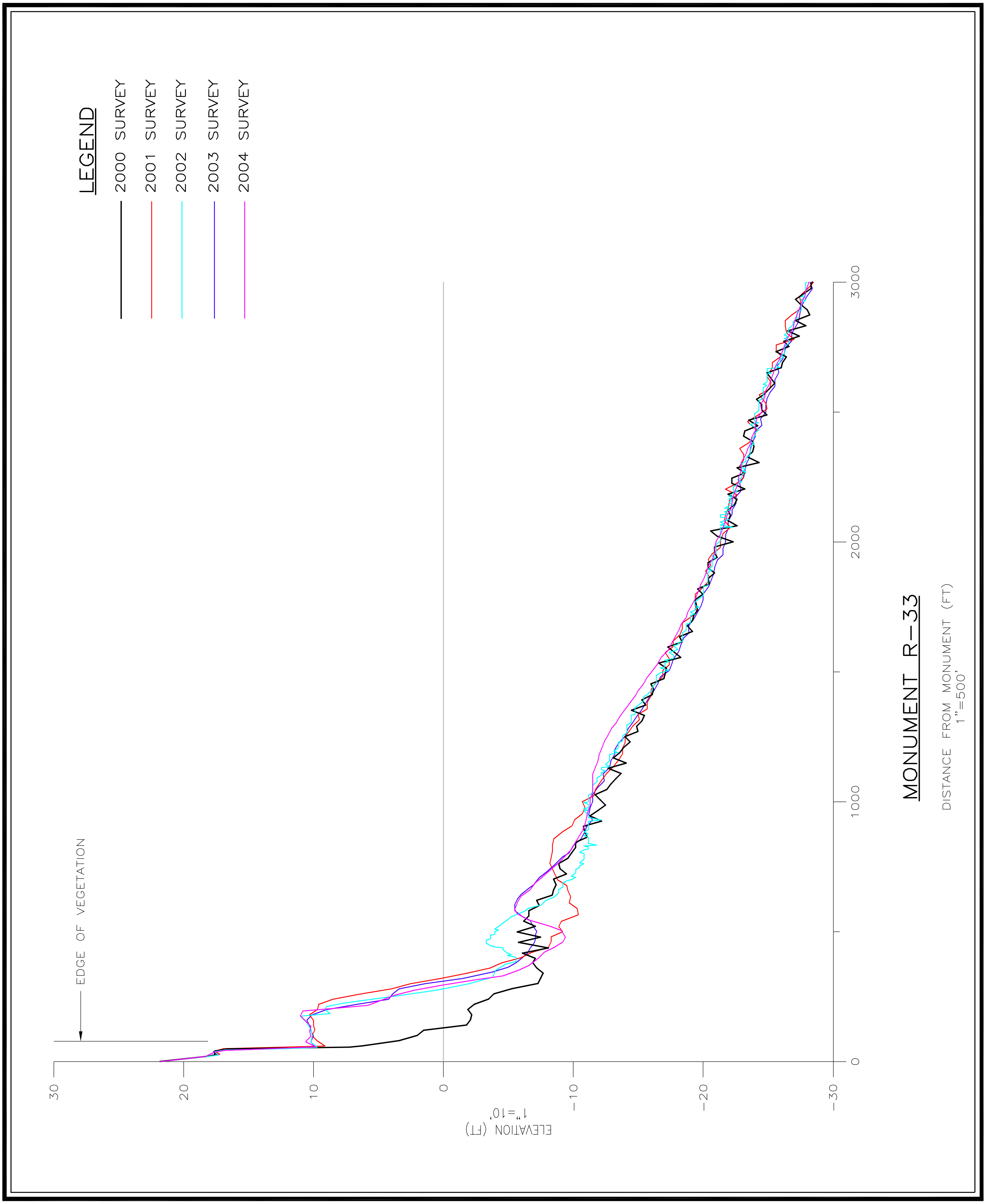

Figure A-10
Beach Profile Comparison at Monument R-33
Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC

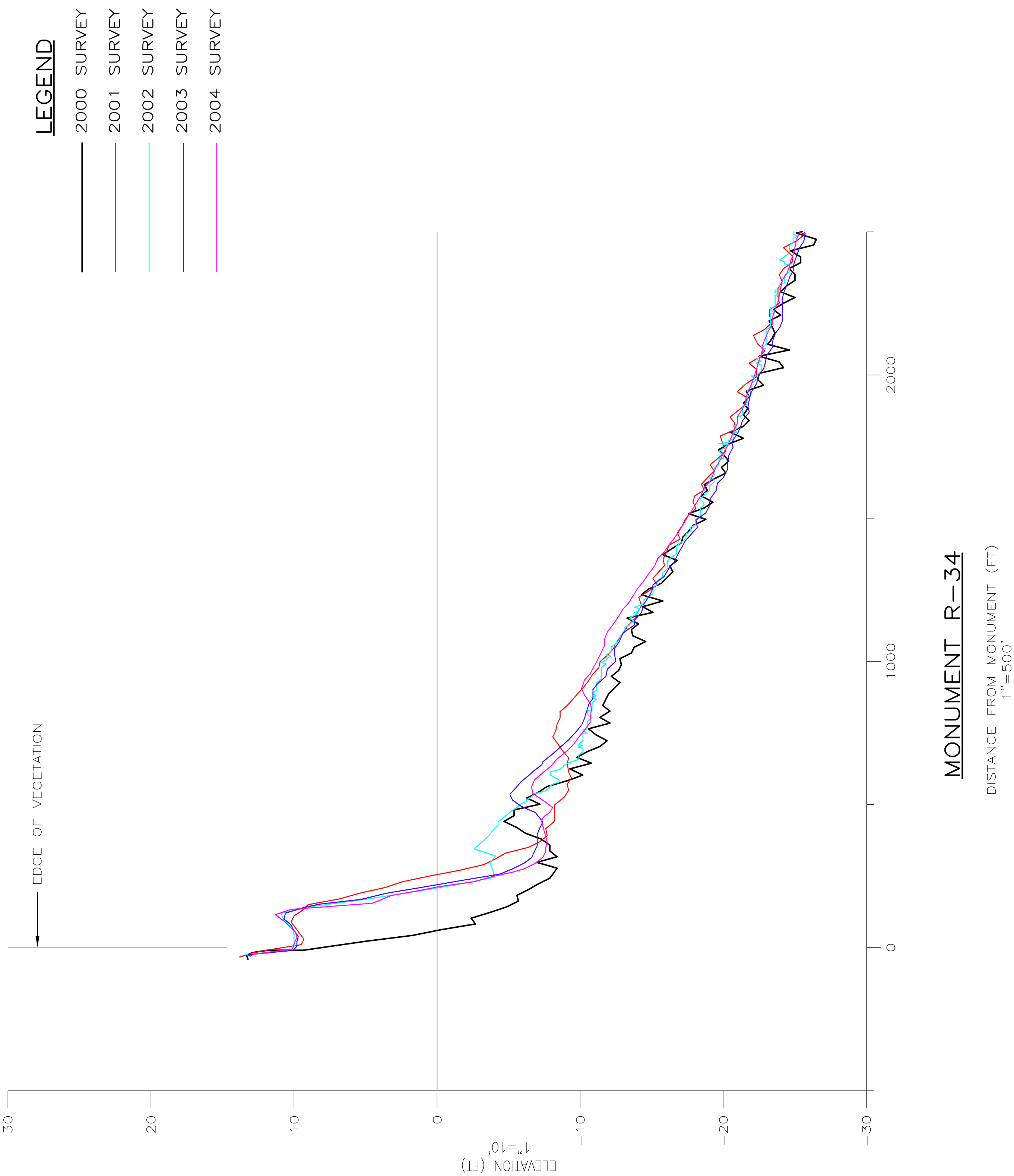

Figure A-11
Beach Profile Comparison at Monument R-34
Juno Beach Shore Protection Project

ATM
APPLIED TECHNOLOGY & MANAGEMENT, INC

04-965 Appendix A - Cross Sections.dwg R-35 4/26/05

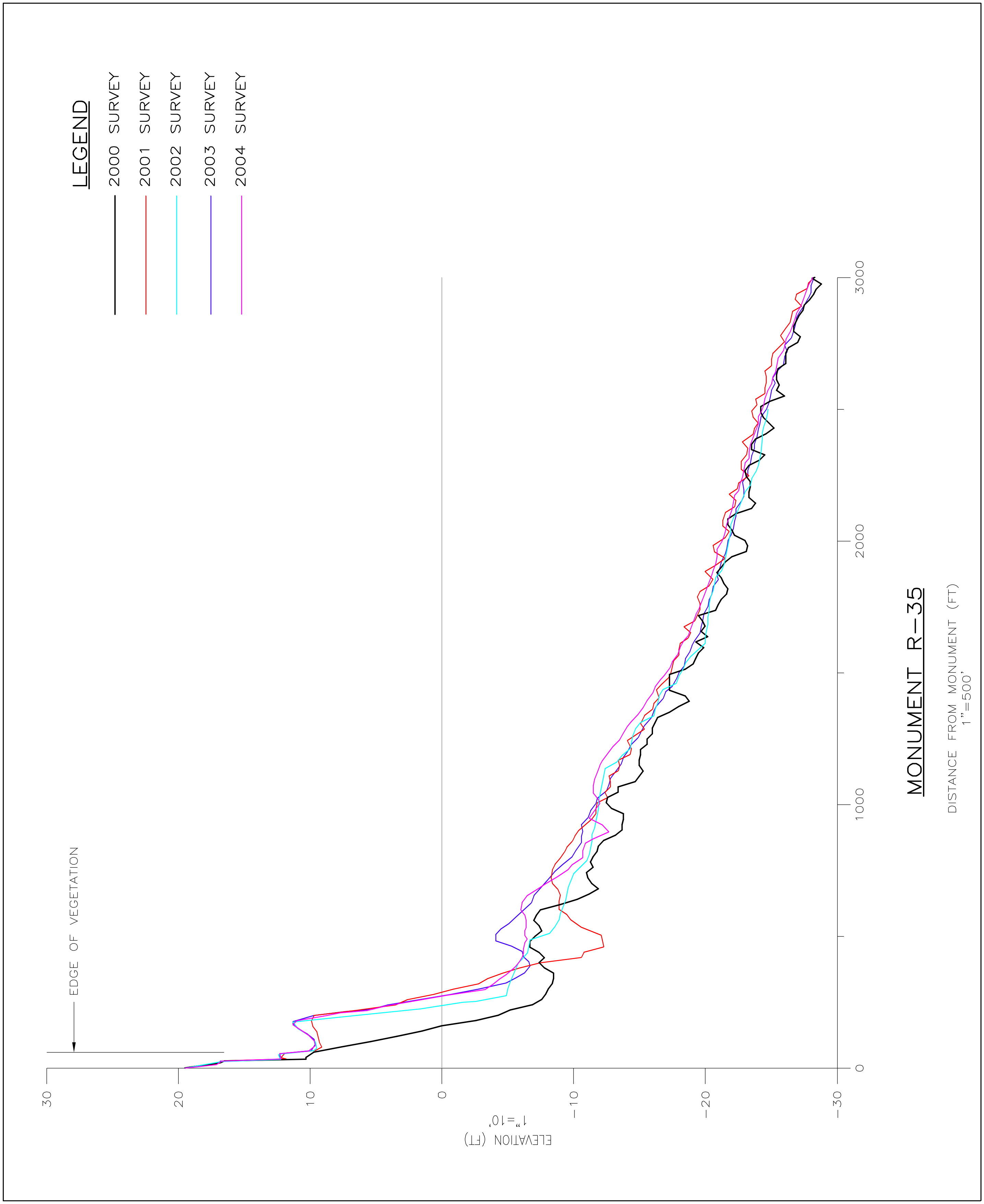

Figure A-12
Beach Profile Comparison at Monument R-35
Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC

04-965 Appendix A - Cross Sections.dwg R-36 4/26/05

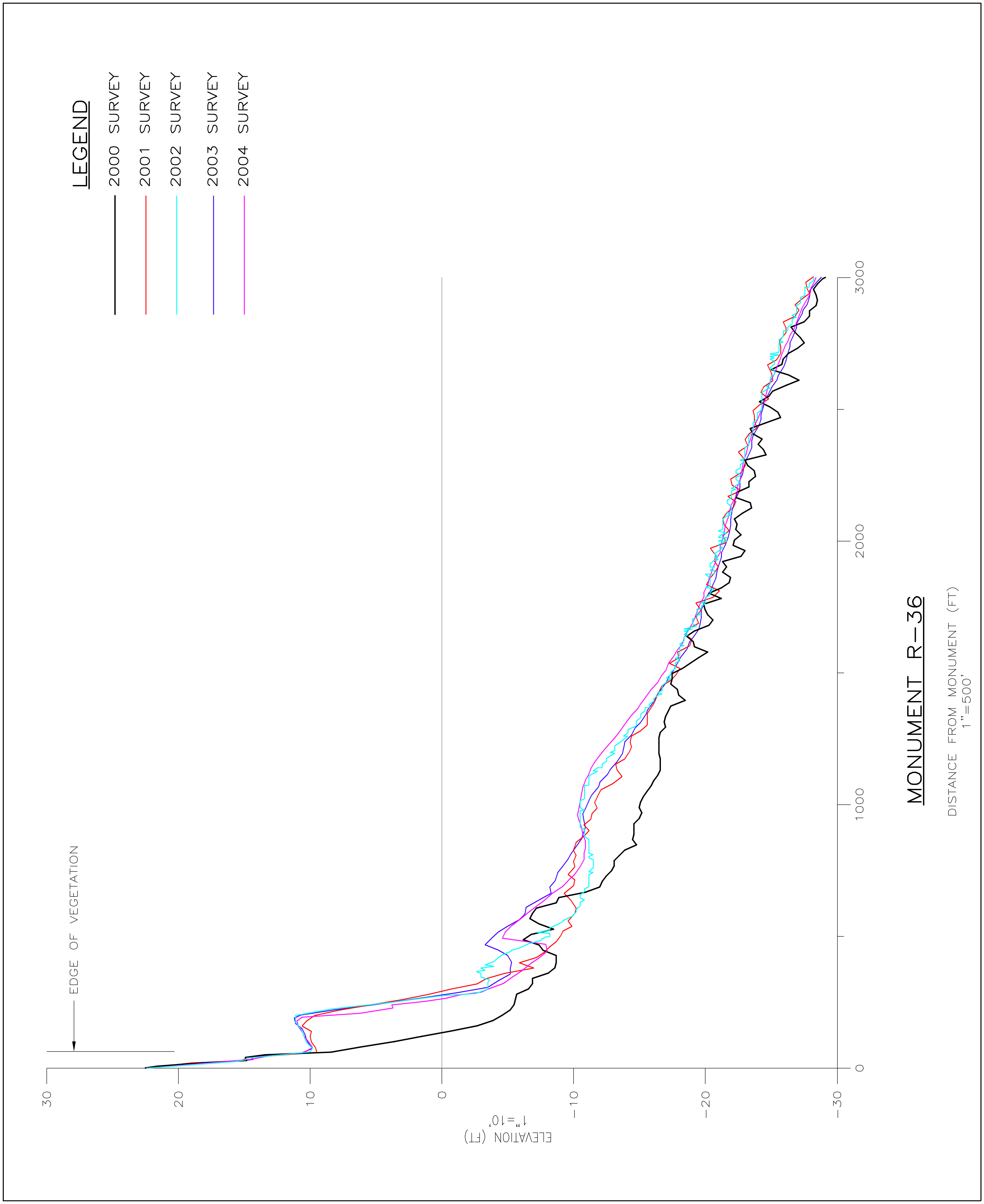

Figure A-13
Beach Profile Comparison at Monument R-36
Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC

04-965 Appendix A - Cross Sections.dwg R-37 4/26/05

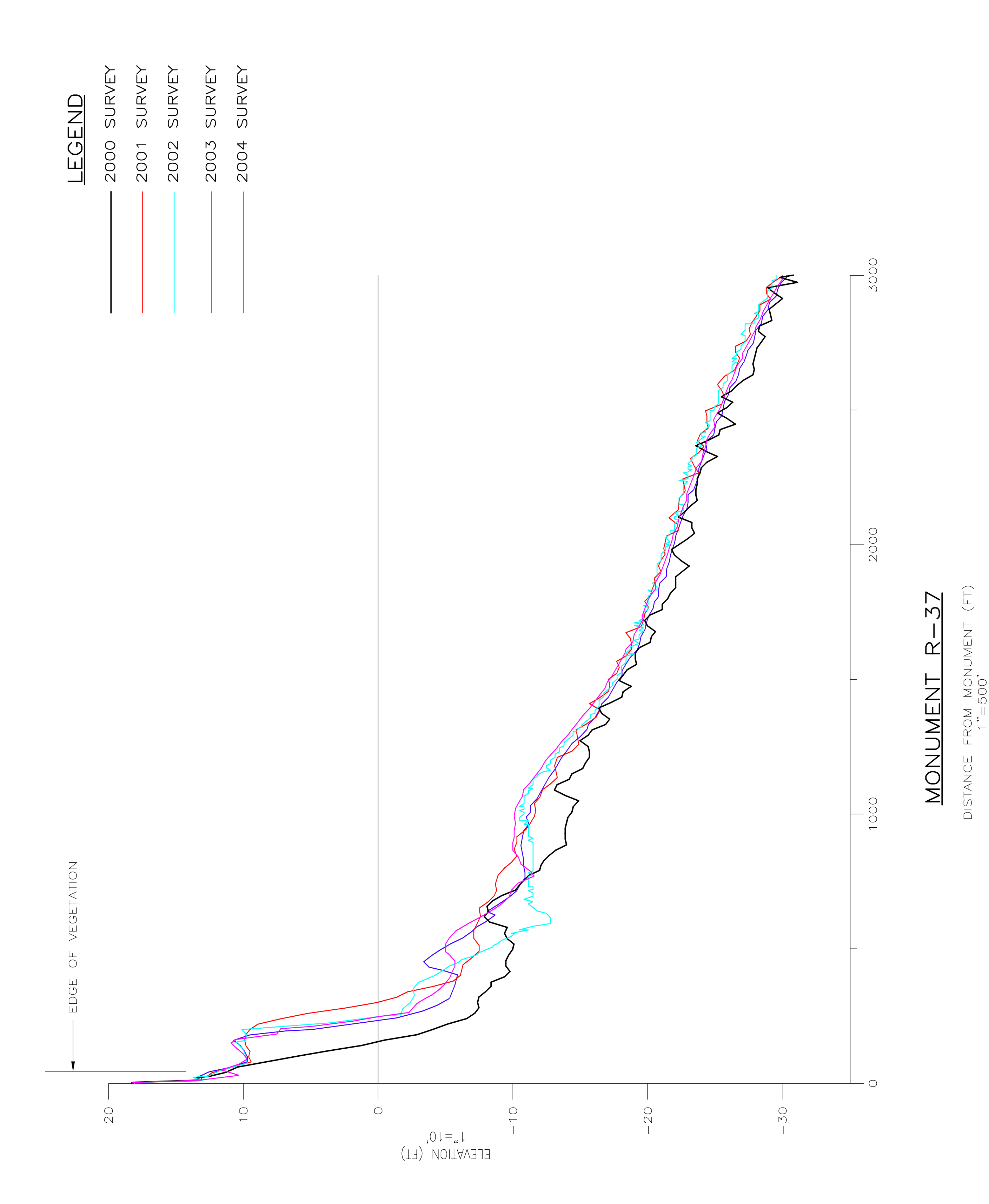

Figure A-14
Beach Profile Comparison at Monument R-37
Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC

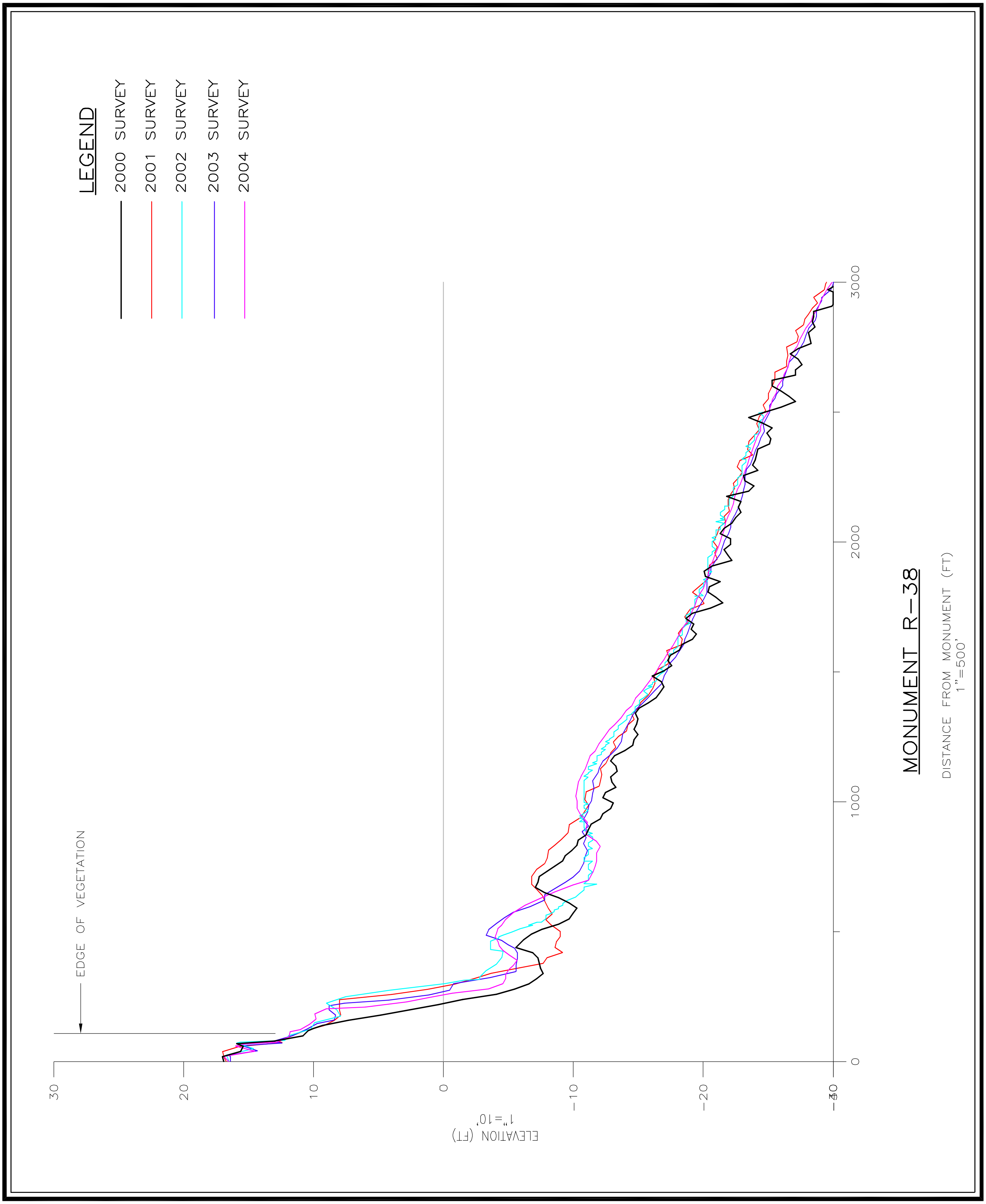

Figure A-15
Beach Profile Comparison at Monument R-38
Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC

04-965 Appendix A - Cross Sections.dwg R-39 4/26/05

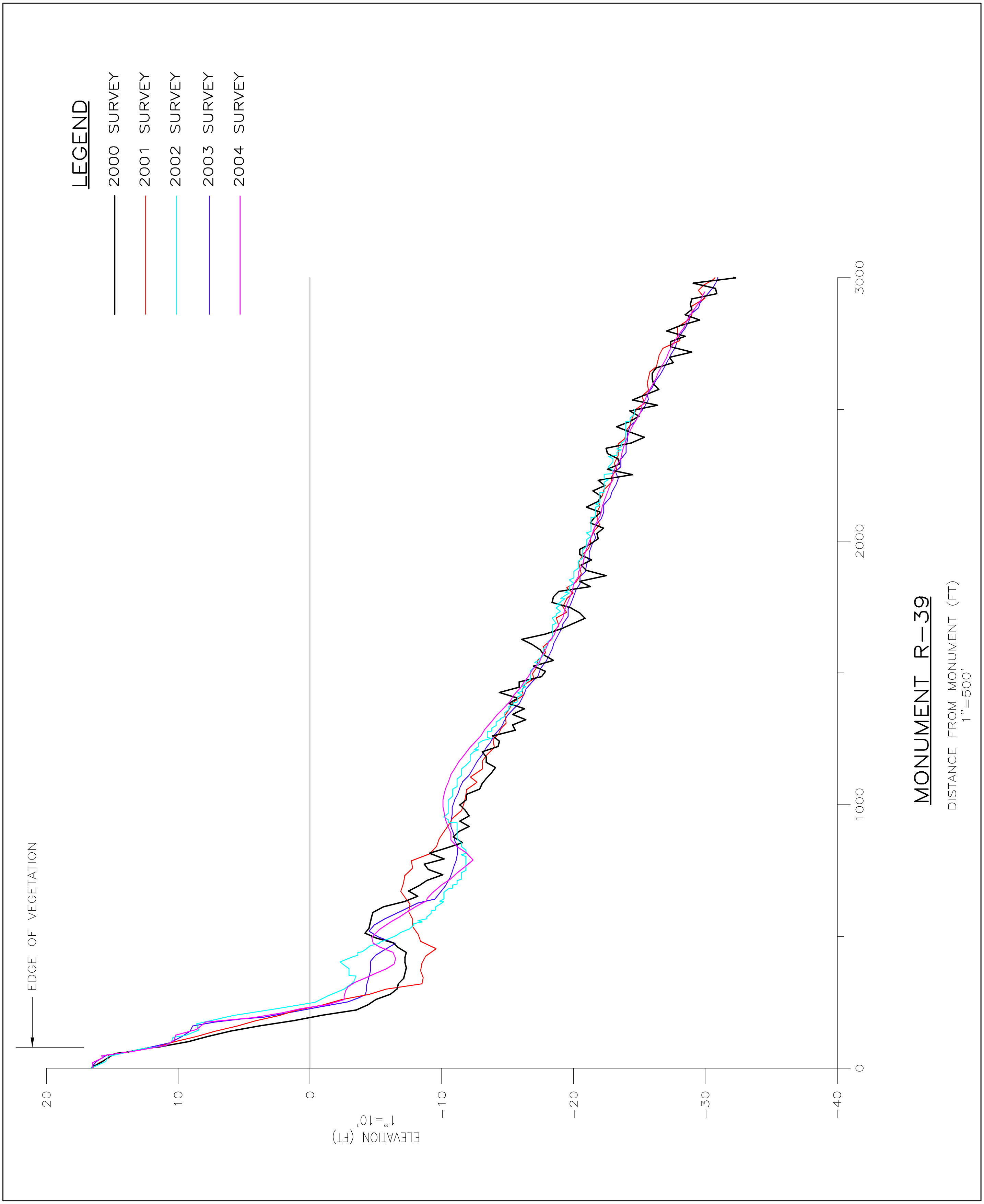

Figure A-16
Beach Profile Comparison at Monument R-39
Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC

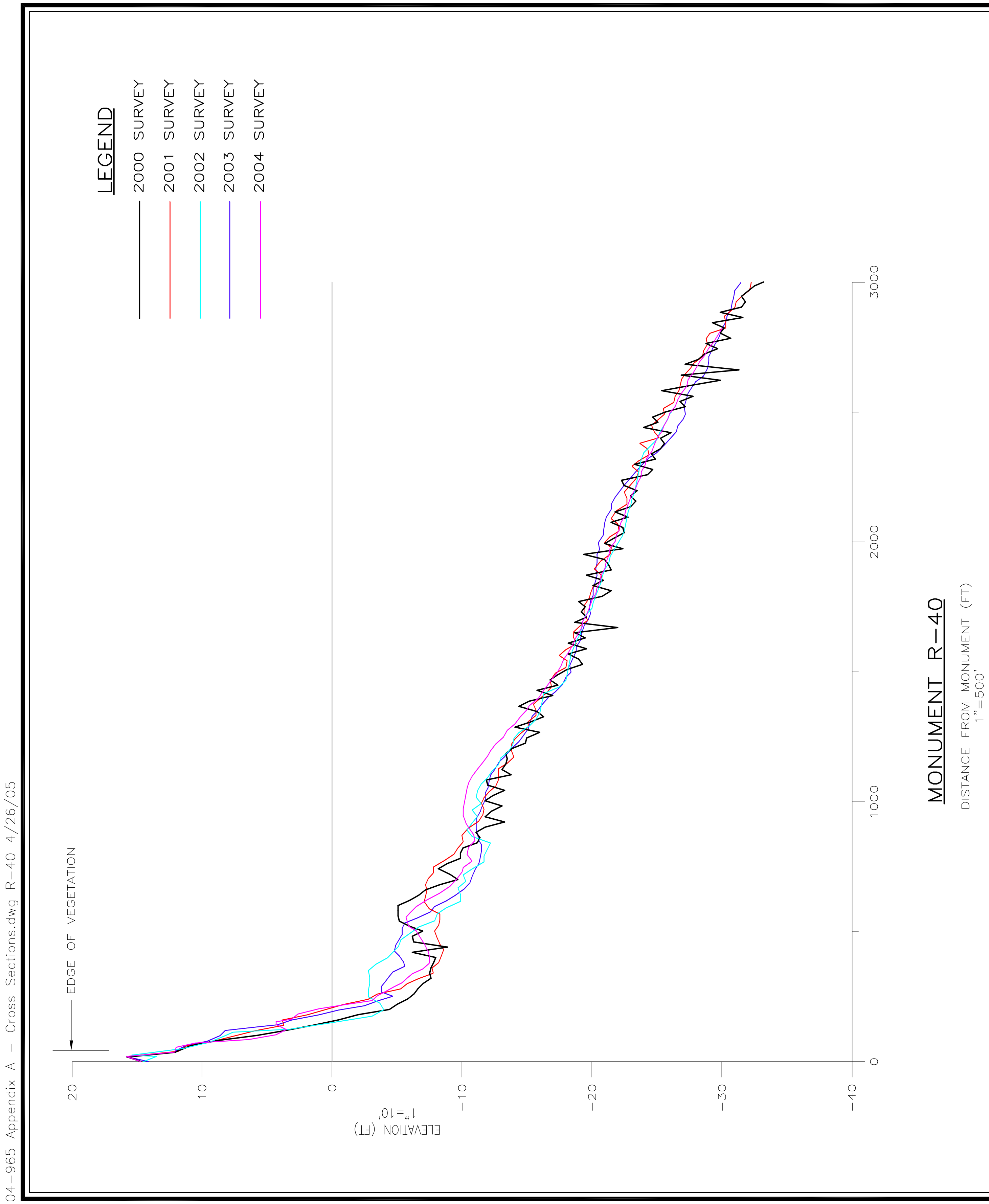

Figure A-17
Beach Profile Comparison at Monument R-40
Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC

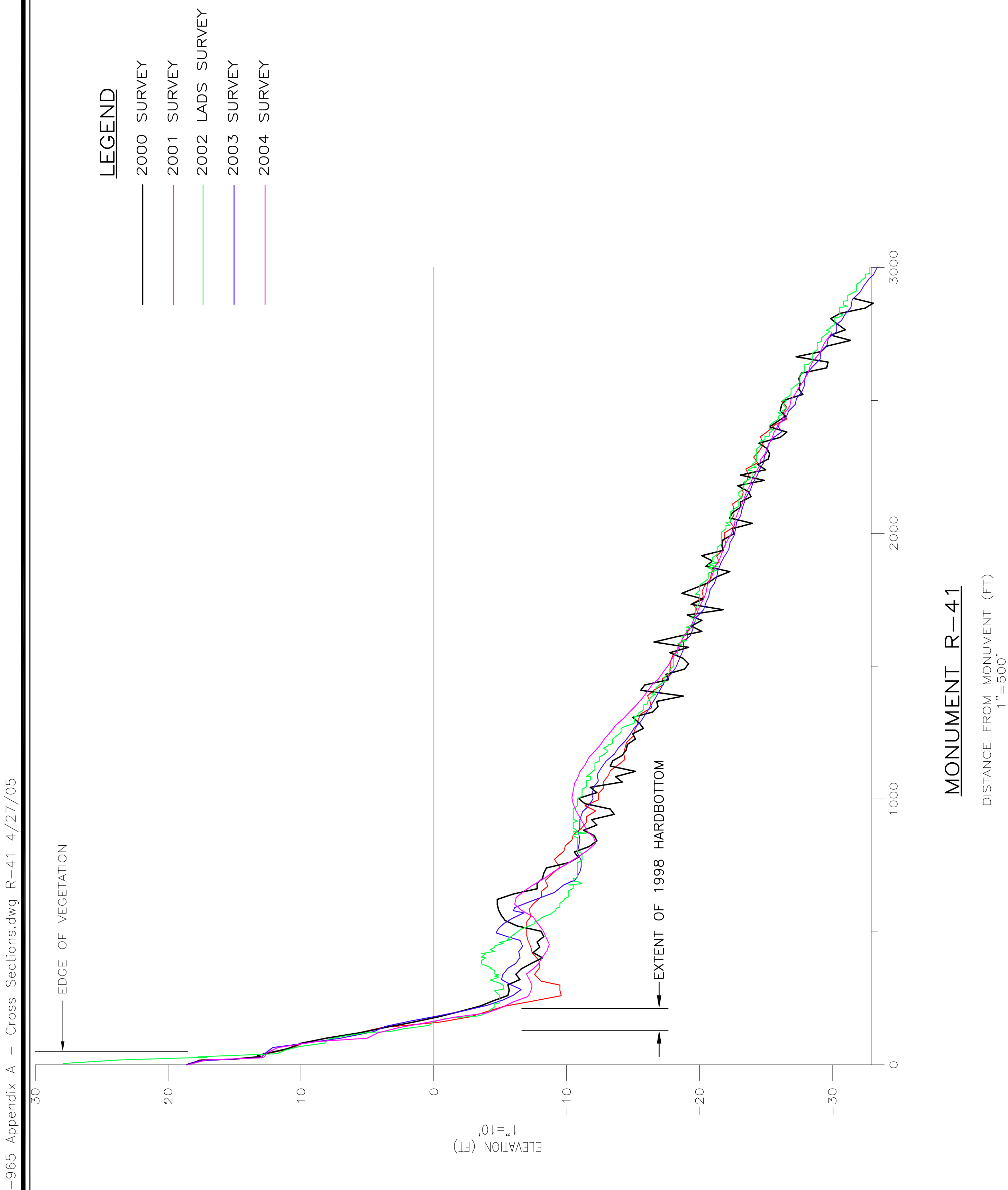

Figure A-18
Beach Profile Comparison at Monument R-41
Juno Beach Shore Protection Project

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04-965 Appendix A - Cross Sections.dwg R-42 4/27/05

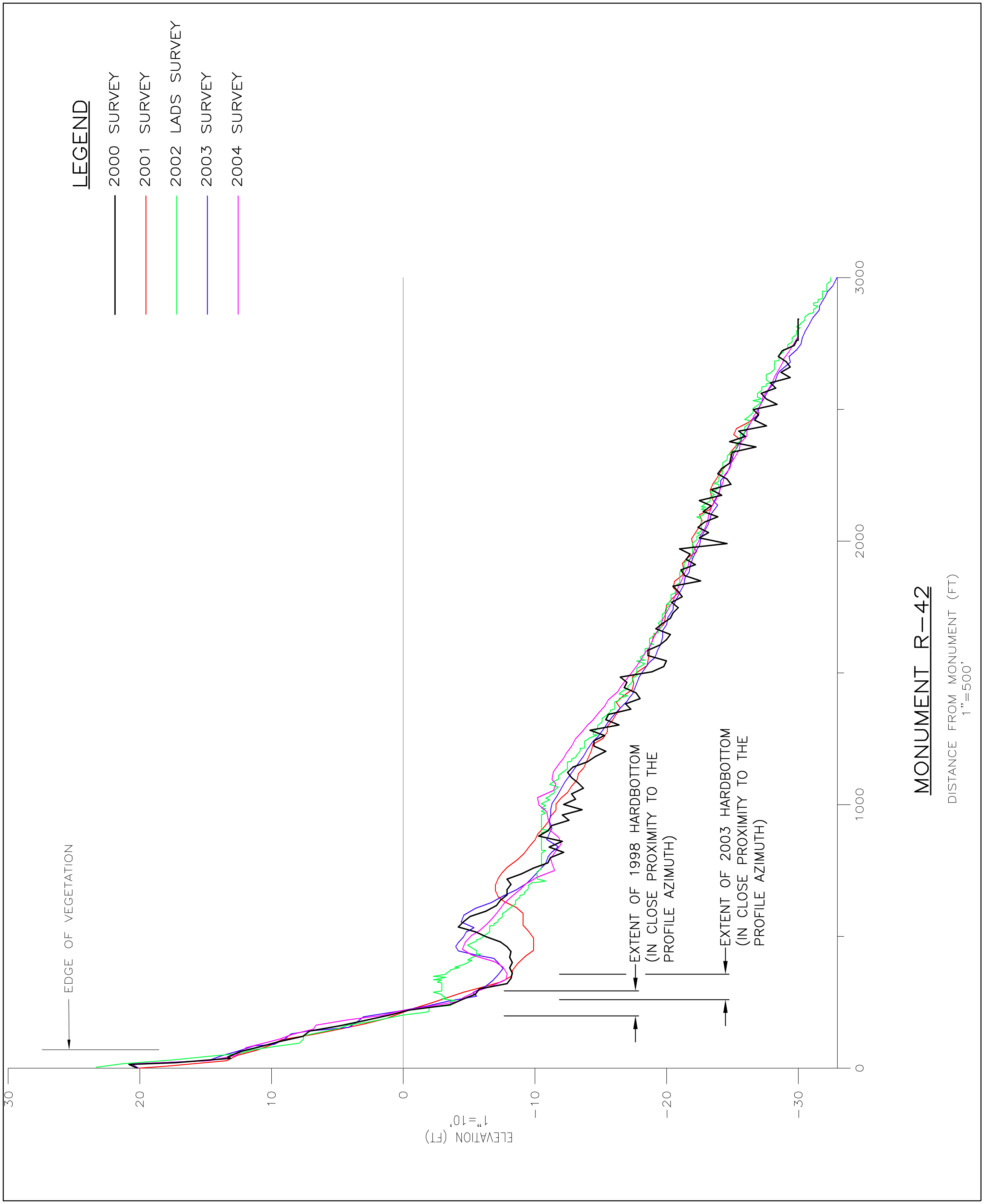

Figure A-19
Beach Profile Comparison at Monument R-42
Juno Beach Shore Protection Project

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04-965 Appendix A - Cross Sections.dwg R-43 4/27/05

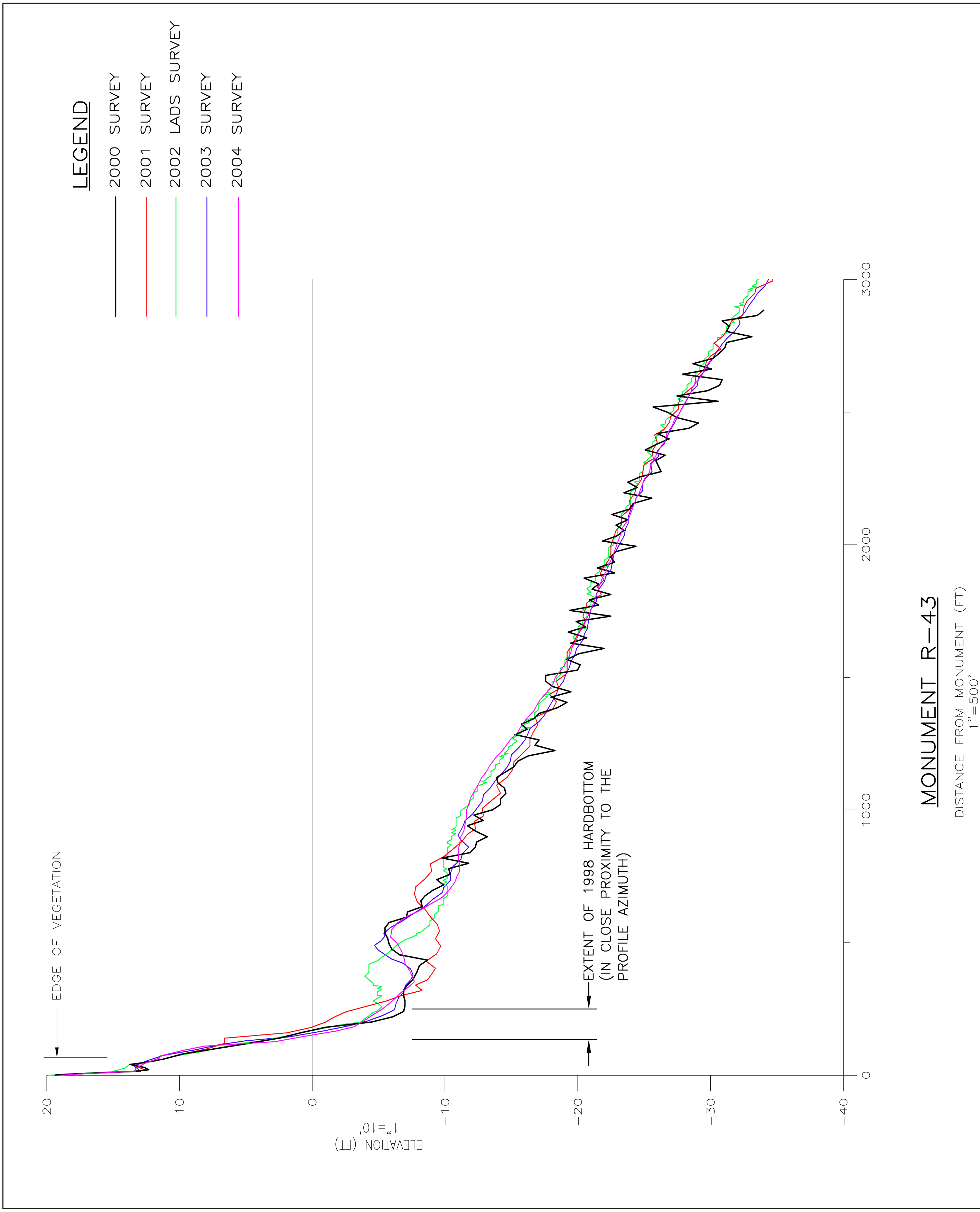

Figure A-20
Beach Profile Comparison at Monument R-43
Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC

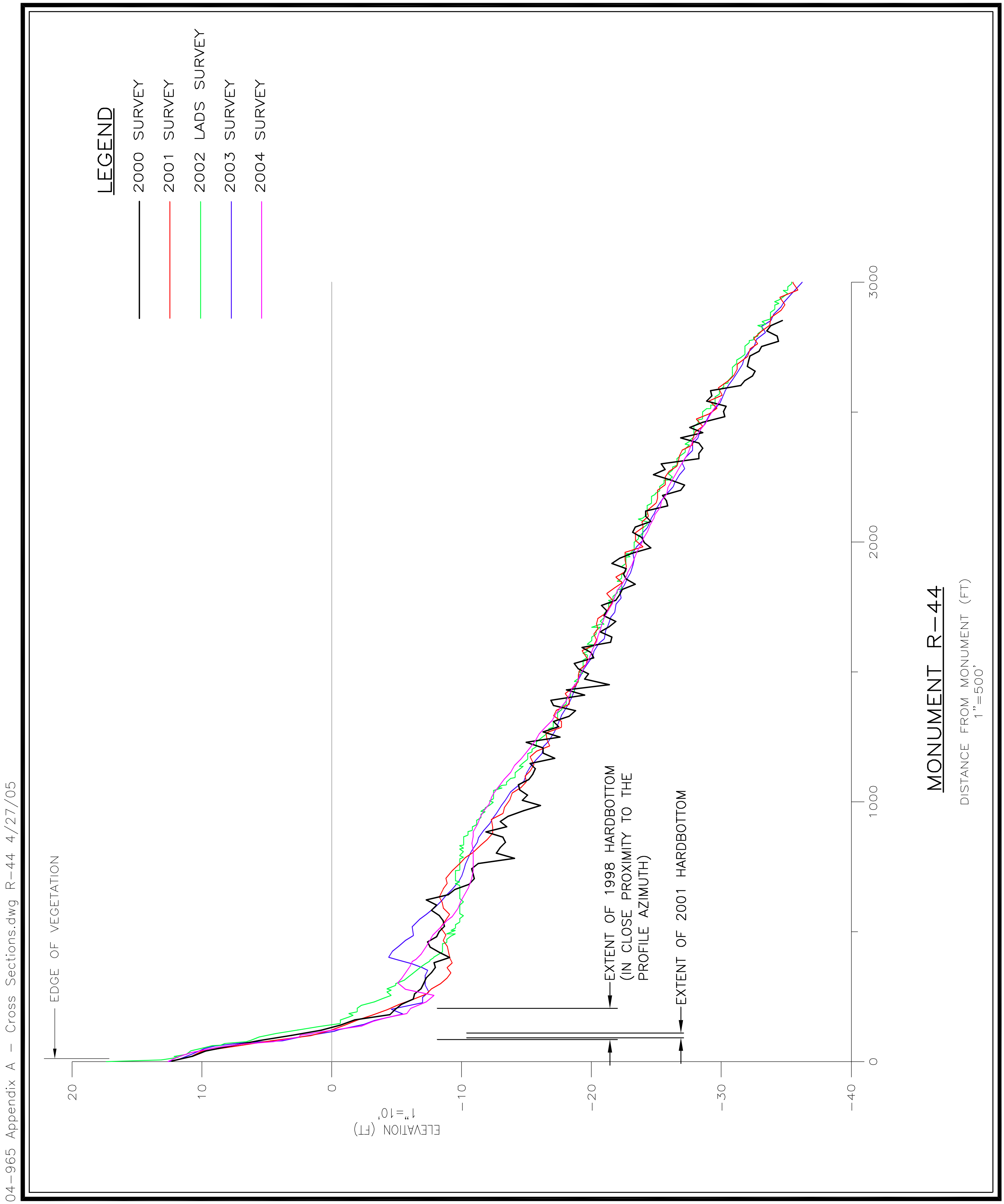

Figure A-21

Beach Profile Comparison at Monument R-44

Juno Beach Shore Protection Project

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Appendix B – Juno Beach Shore Protection Project Nearshore Hardbottom Comparison

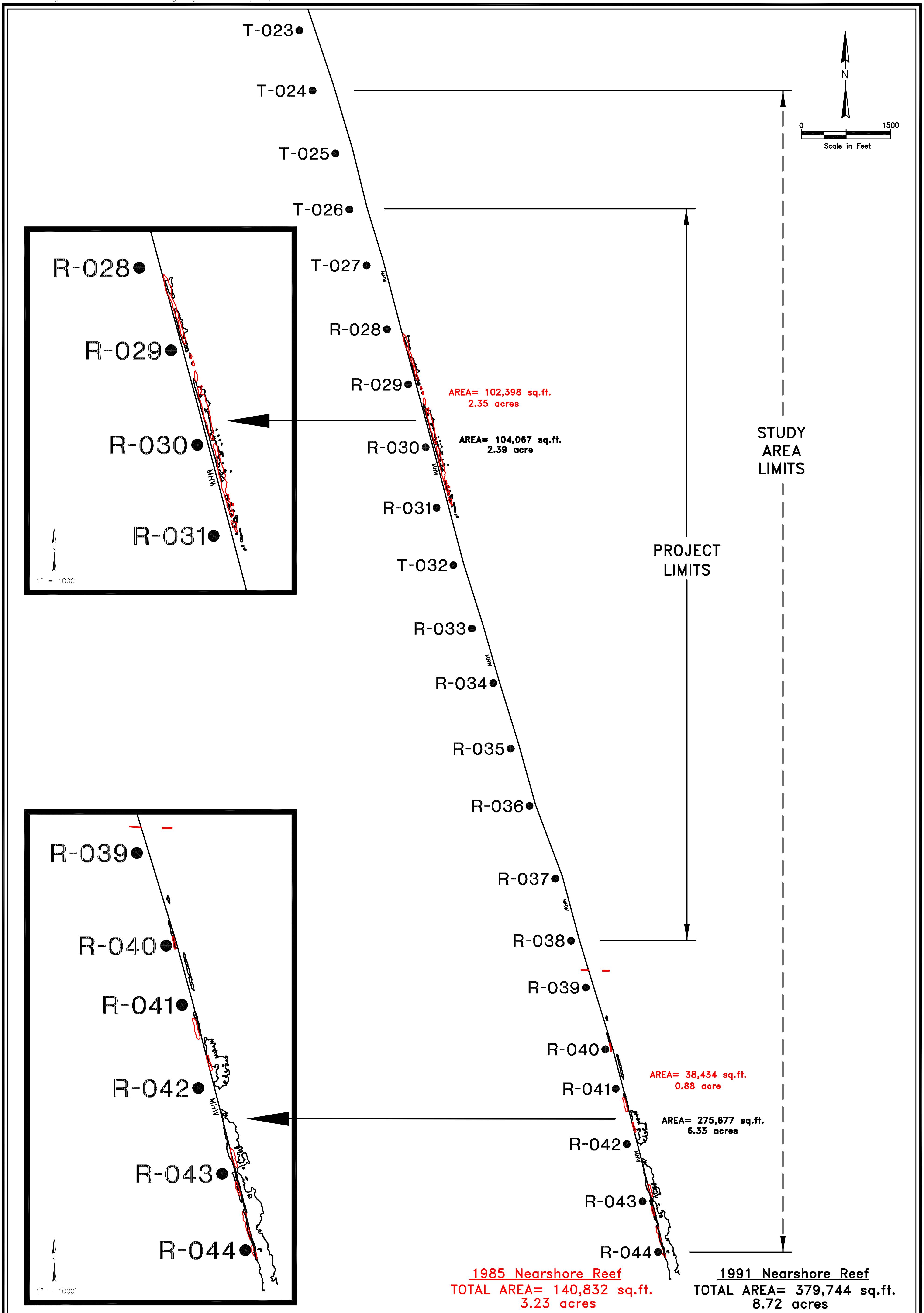


Figure B-1
Comparison of Exposed Hardbottom
Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC

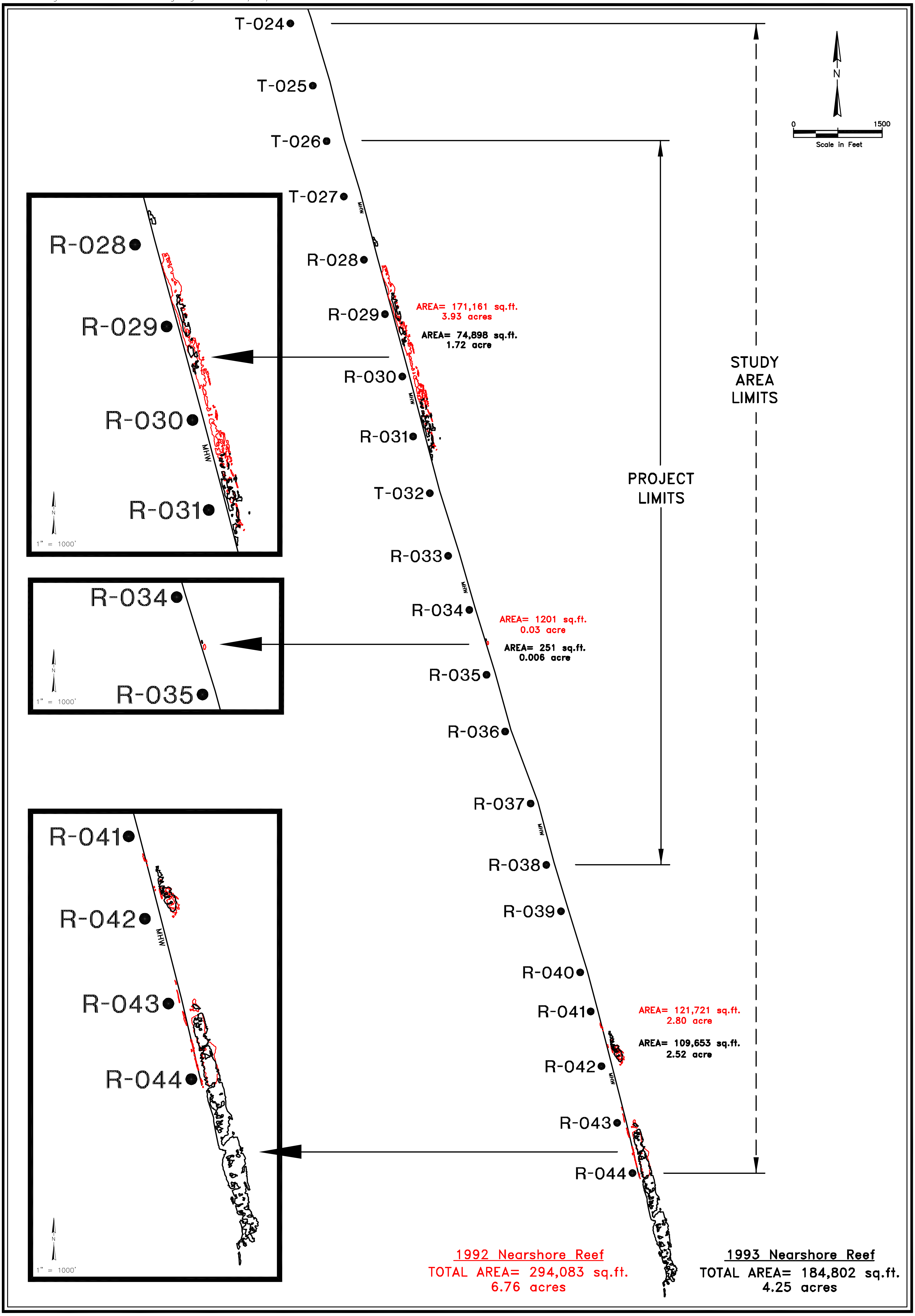


Figure B-2
Comparison of Exposed Hardbottom
Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC

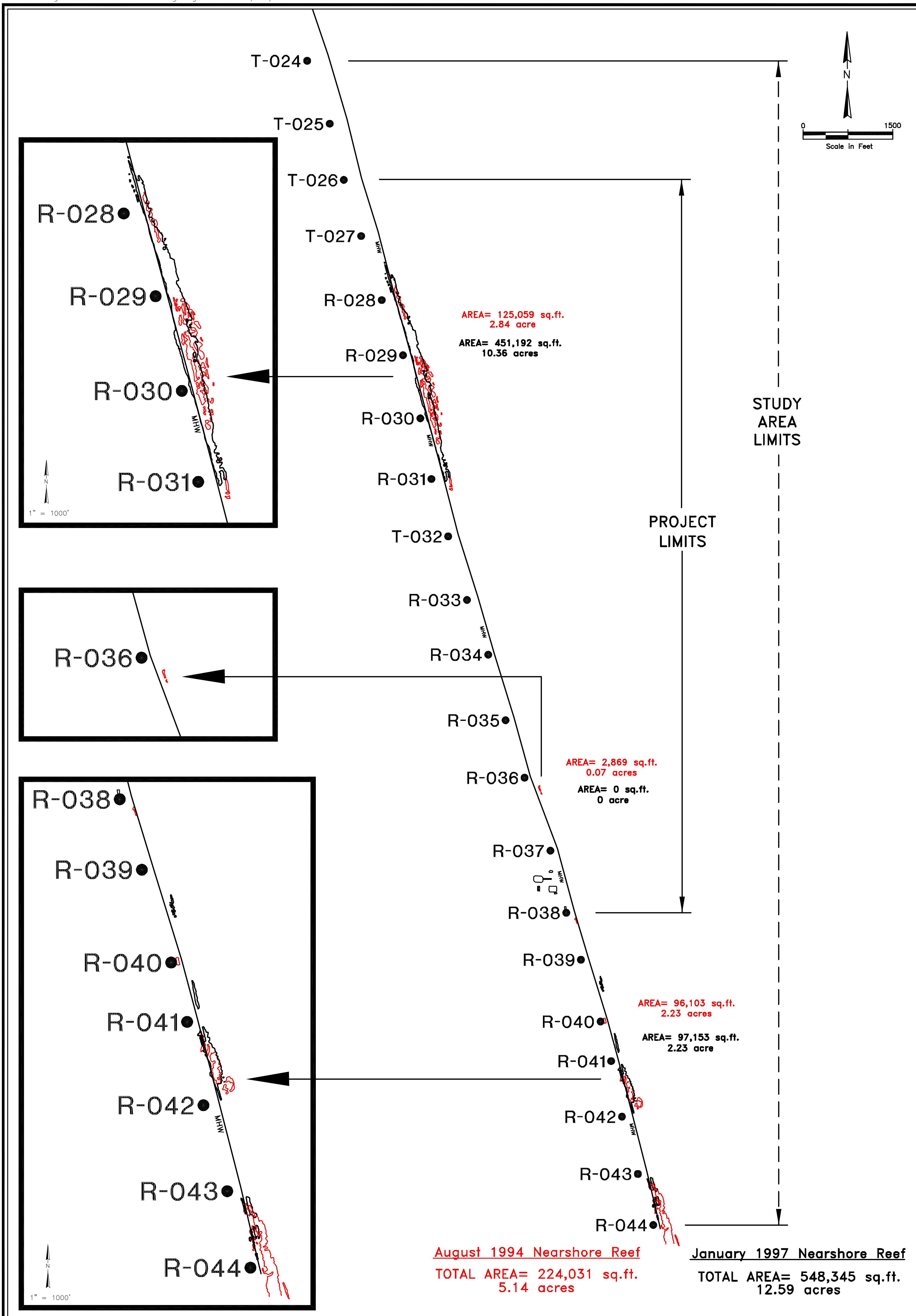
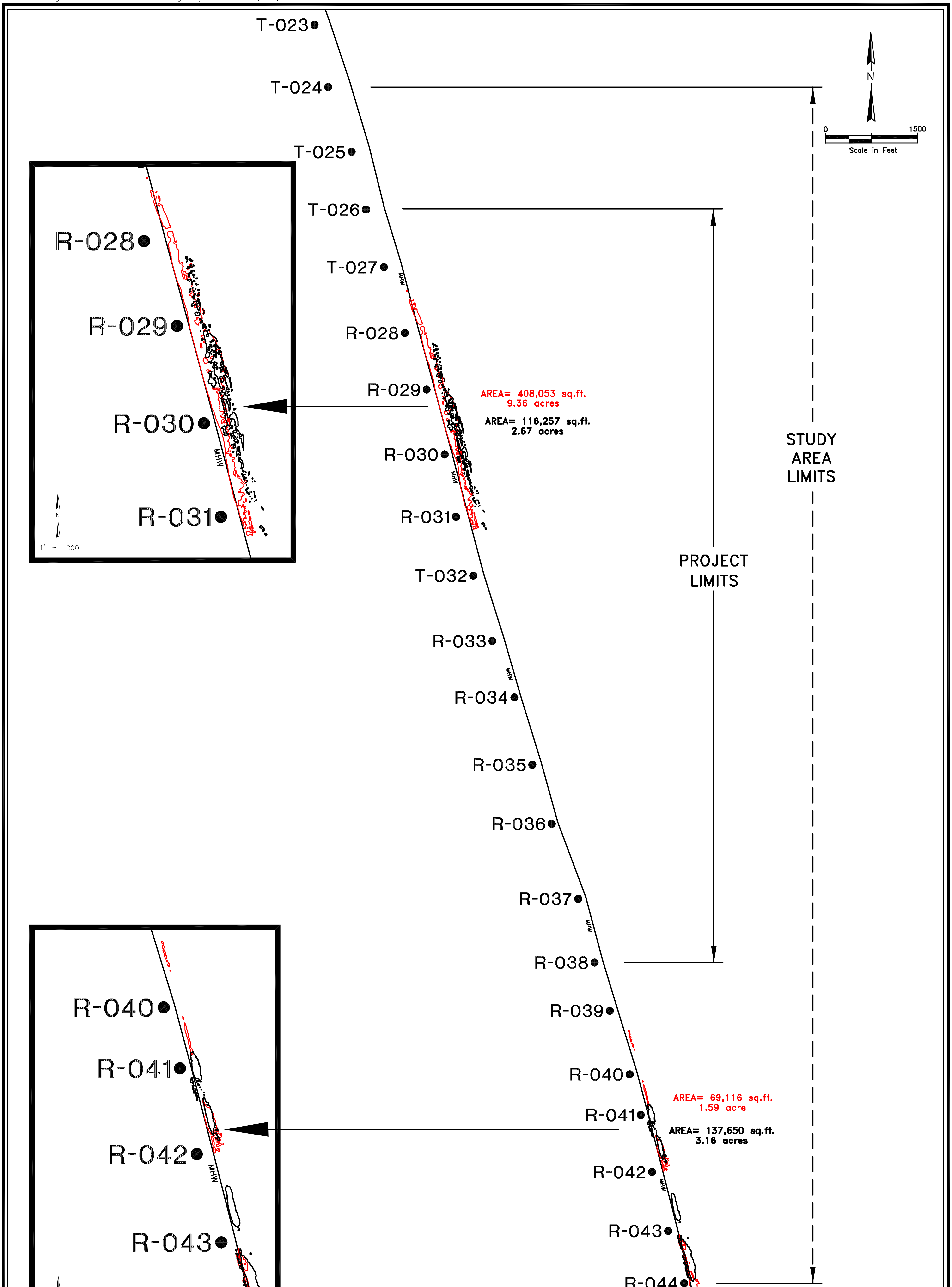


Figure B-3
Comparison of Exposed Hardbottom
Juno Beach Shore Protection Project

ATM
APPLIED TECHNOLOGY & MANAGEMENT, INC



August 1997 Nearshore Reef

TOTAL AREA= 477,169 sq.ft.
10.95 acres

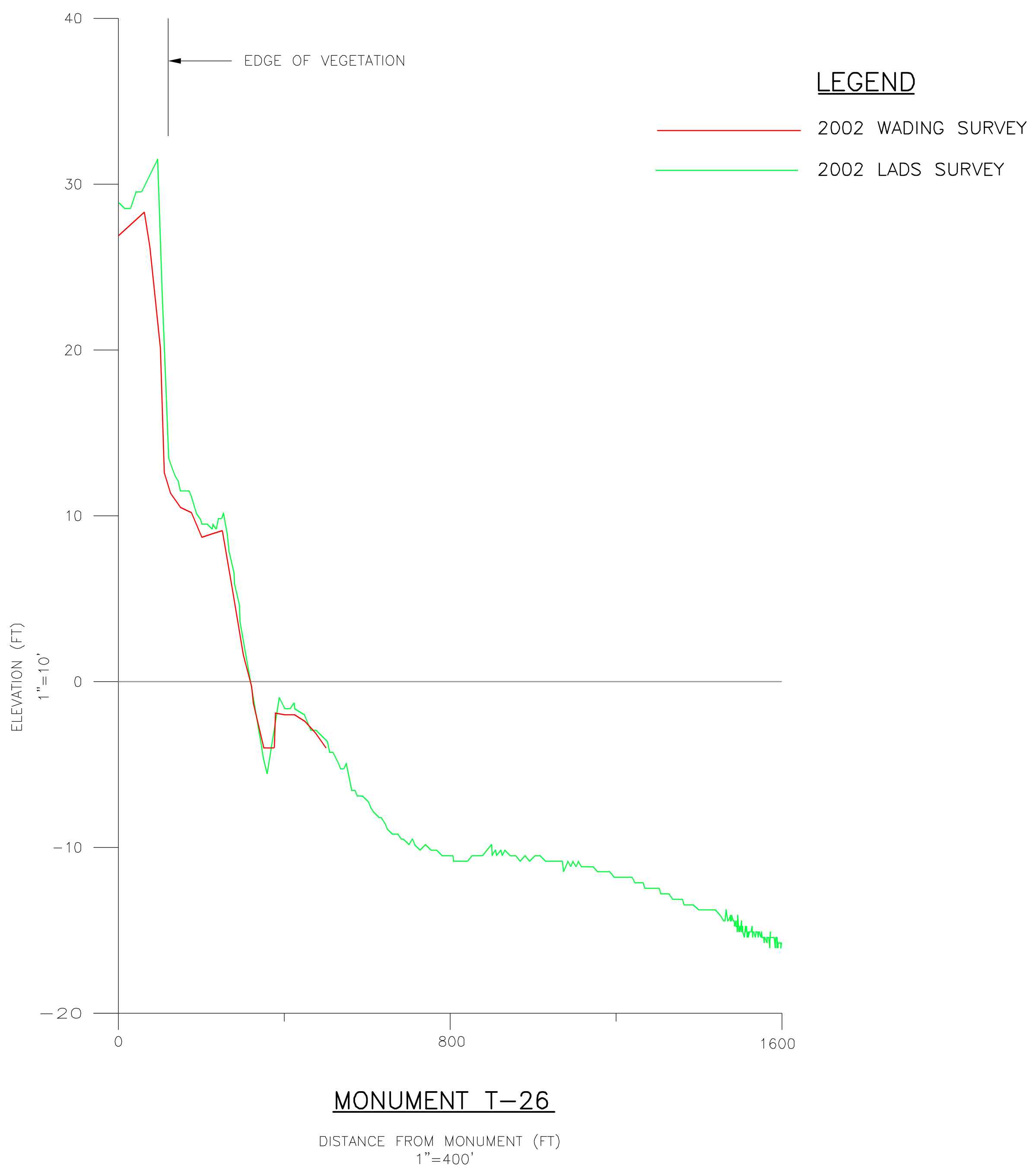
May 1998 Nearshore Hardbottom

FILL AREA= 253,907 sq.ft.
5.83 acres

Figure B-4
Comparison of Exposed Hardbottom
Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC

Appendix C – Juno Beach Shore Protection Project
Comparison Plots of
2002 Wading Profiles and 2002 LADS Profiles



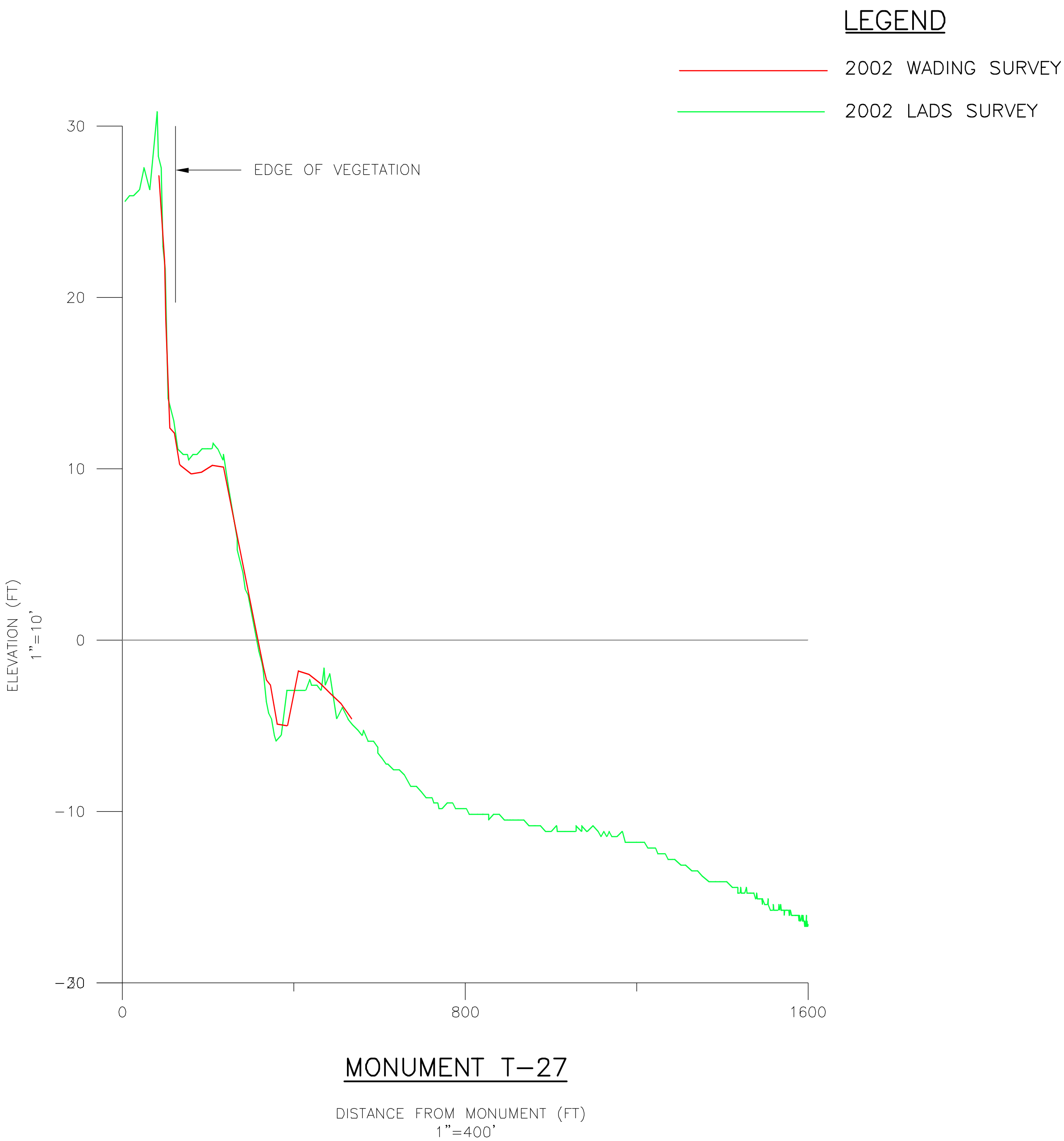
04−965 Appendix C − Cross Sections.dwg T−26 1/28/05

Figure C−1

T−26 Profile Comparison of LADS Data and 2002 Wading (Traditional) Profiles

Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC



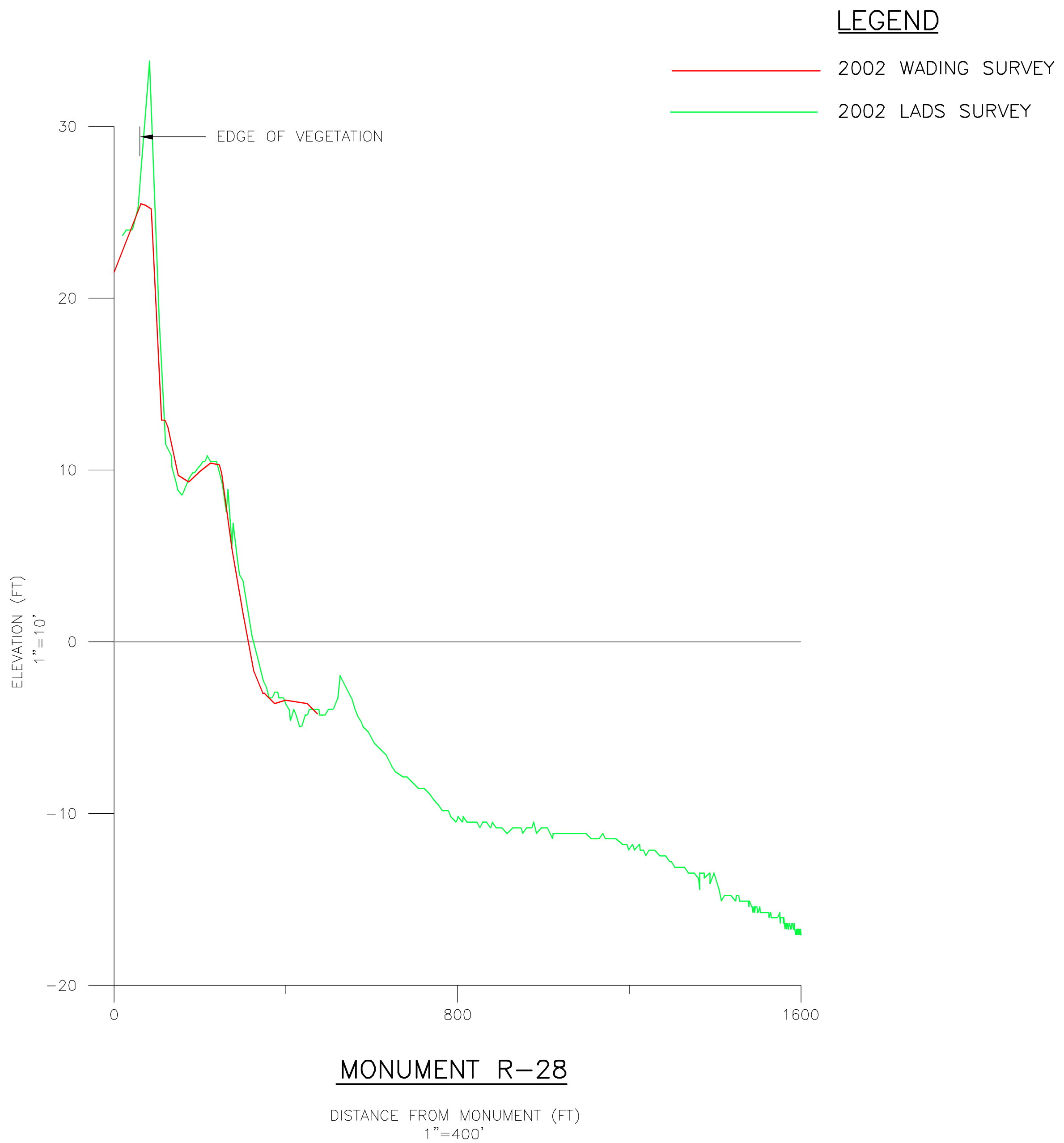
04-965 Appendix C - Cross Sections.dwg T-27 4/26/05

Figure C-2

T-27 Profile Comparison of LADS Data and 2002 Wading (Traditional) Profiles

Juno Beach Shore Protection Project

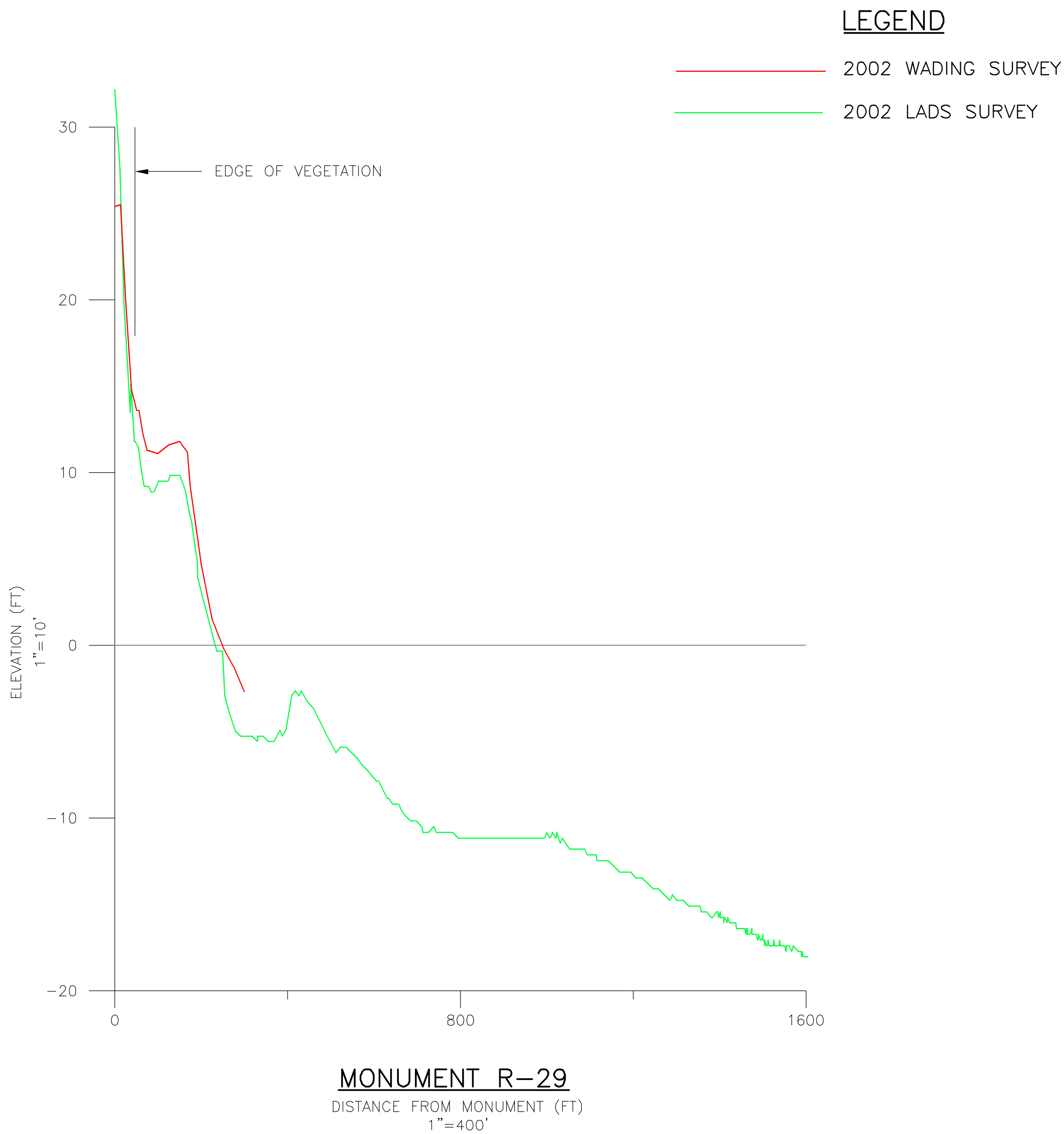
APPLIED TECHNOLOGY & MANAGEMENT, INC



04-965 Appendix C - Cross Sections.dwg R-28 4/26/05

Figure C-3
R-28 Profile Comparison of LADS Data and 2002 Wading (Traditional) Profiles
Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC



04−965 Appendix C − Cross Sections.dwg R−29 4/26/05

Figure C−4

R−29 Profile Comparison of LADS Data and 2002 Wading (Traditional) Profiles

Juno Beach Shore Protection Project

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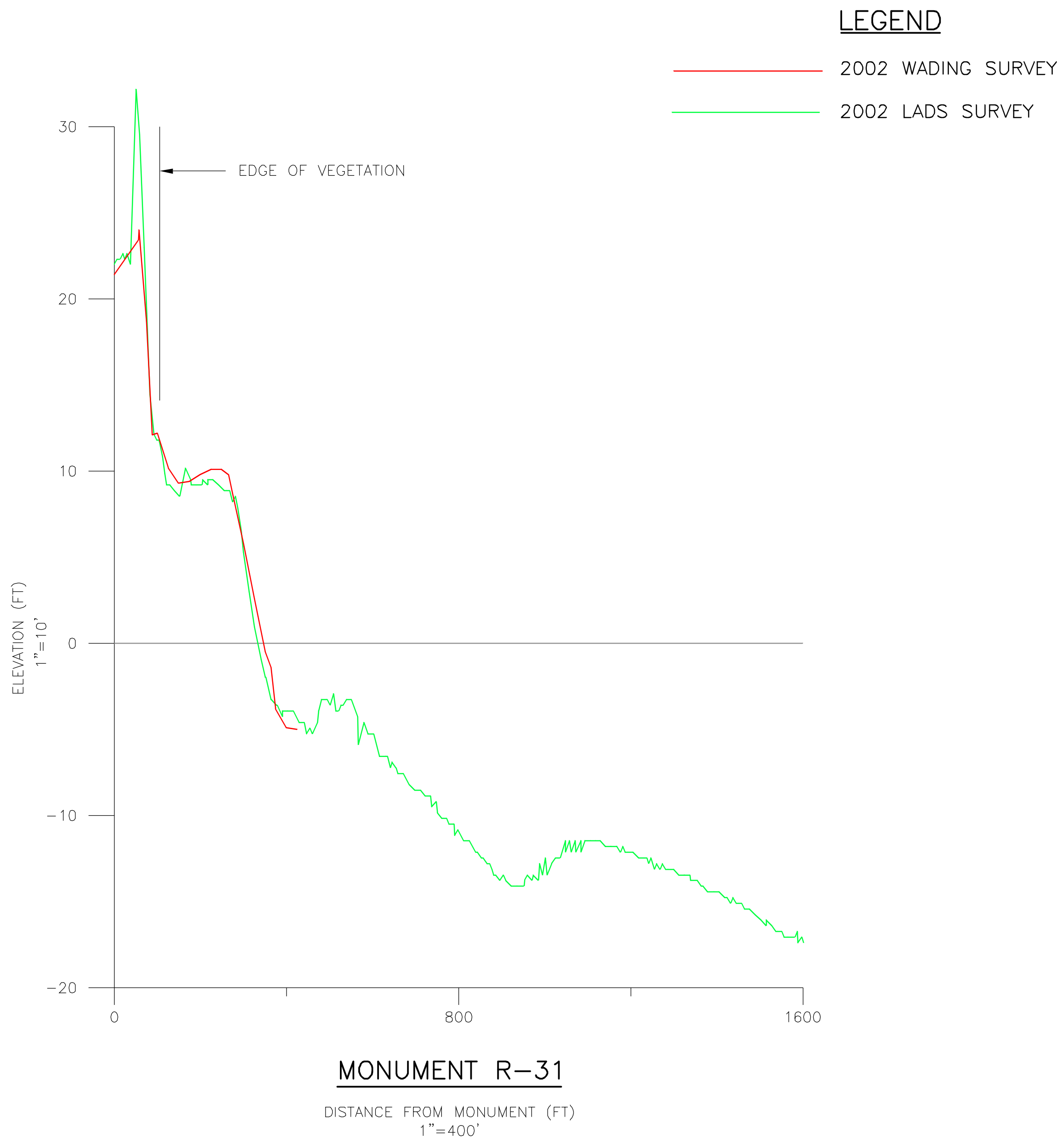

04-965 Appendix C - Cross Sections.dwg R-31 4/26/05

Figure C-5

R-31 Profile Comparison of LADS Data and 2002 Wading (Traditional) Profiles

Juno Beach Shore Protection Project

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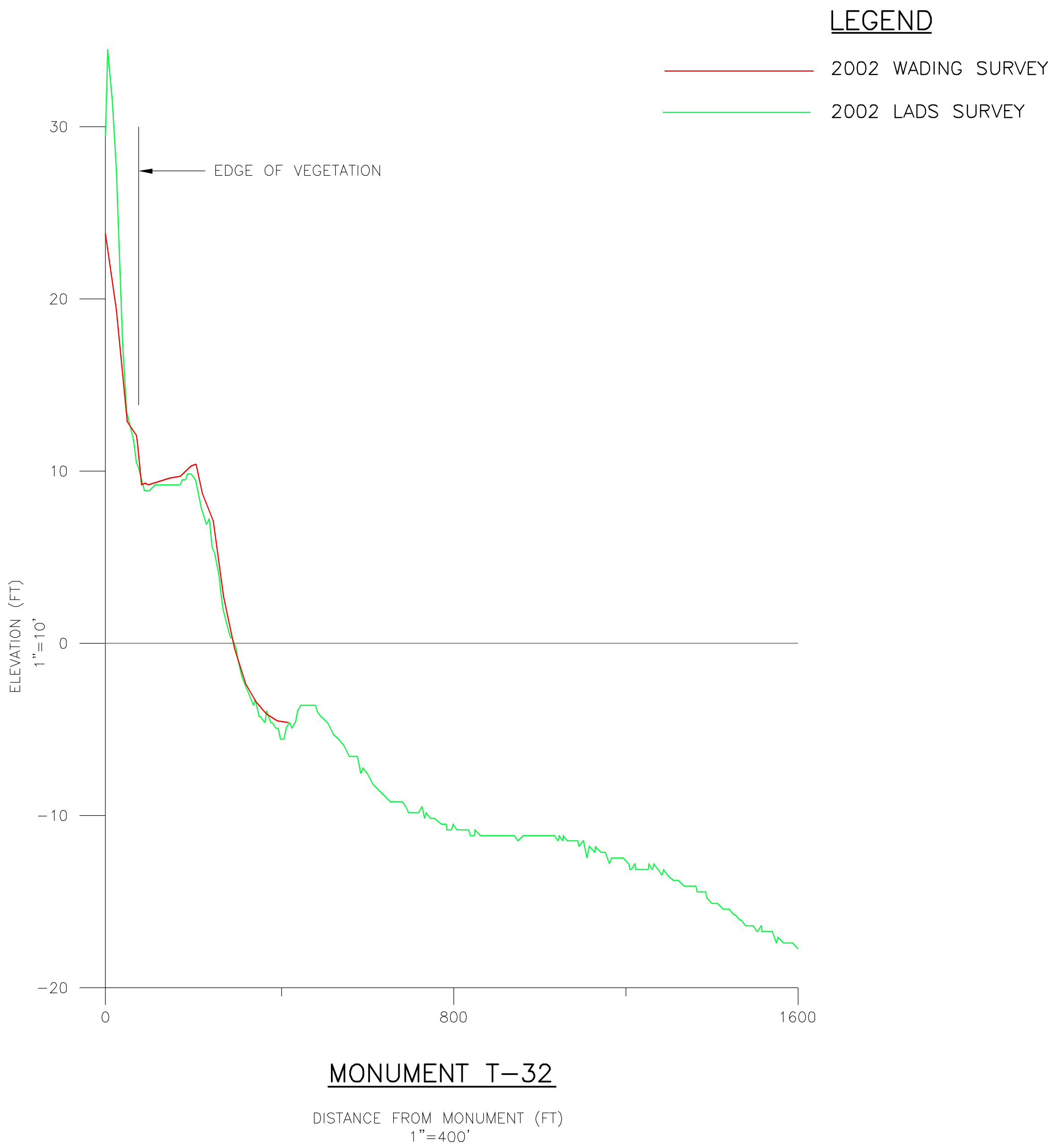

04-965 Appendix C - Cross Sections.dwg T-32 4/26/05

Figure C-6

T-32 Profile Comparison of LADS Data and 2002 Wading (Traditional) Profiles

Juno Beach Shore Protection Project

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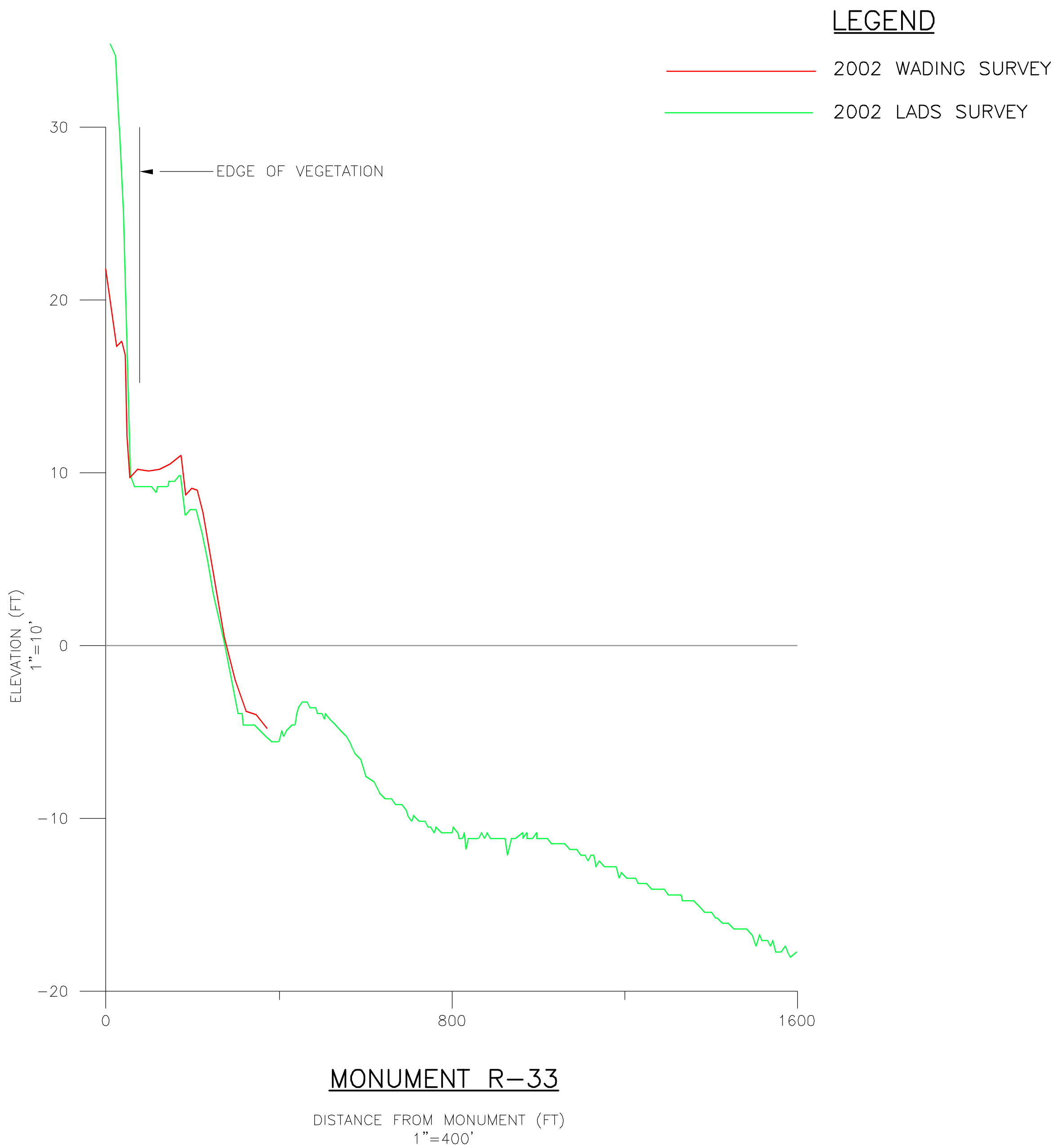
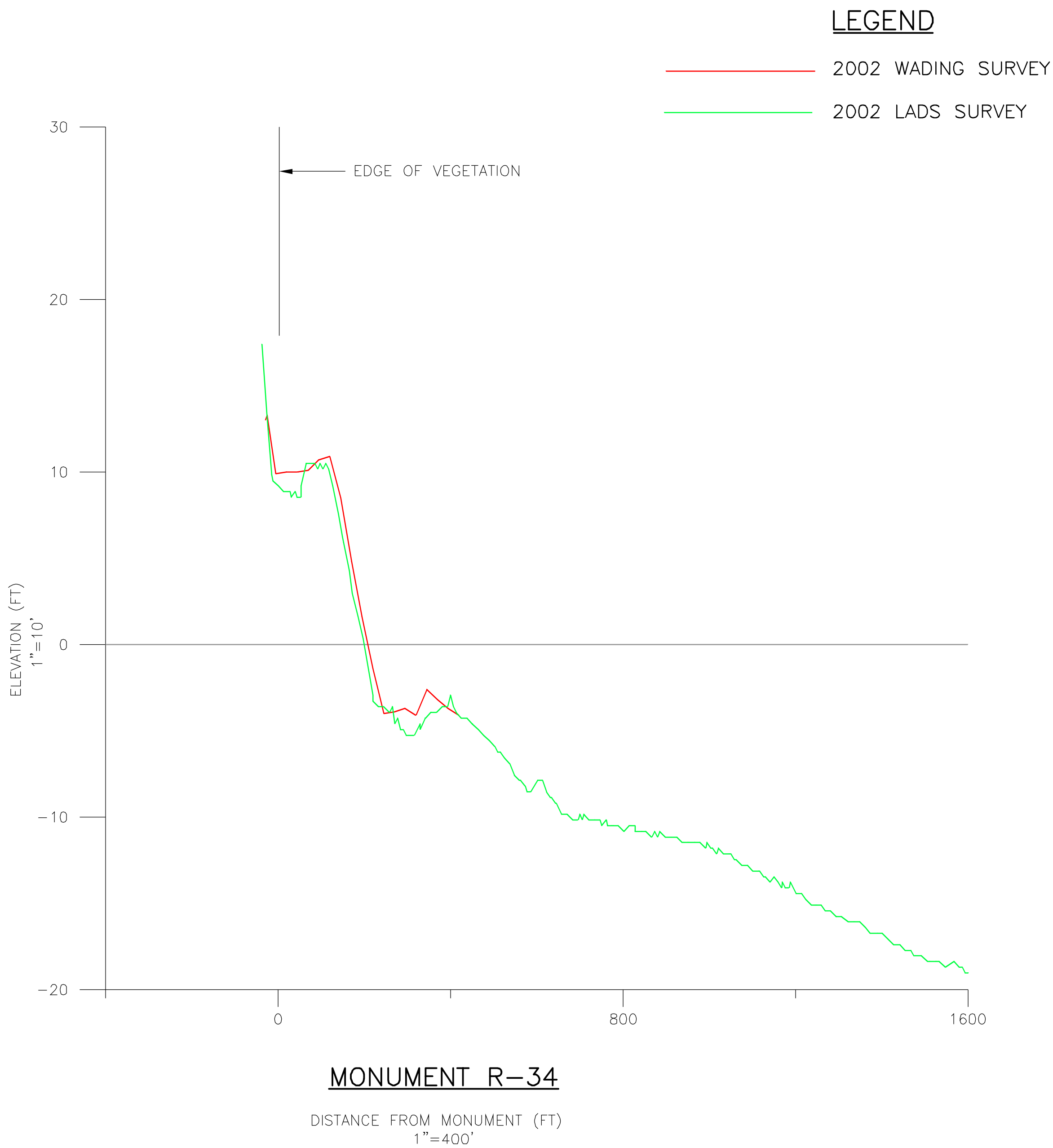


04-965 Appendix C - Cross Sections.dwg R-33 4/26/05

Figure C-7
R-33 Profile Comparison of LADS Data and 2002 Wading (Traditional) Profiles
Juno Beach Shore Protection Project

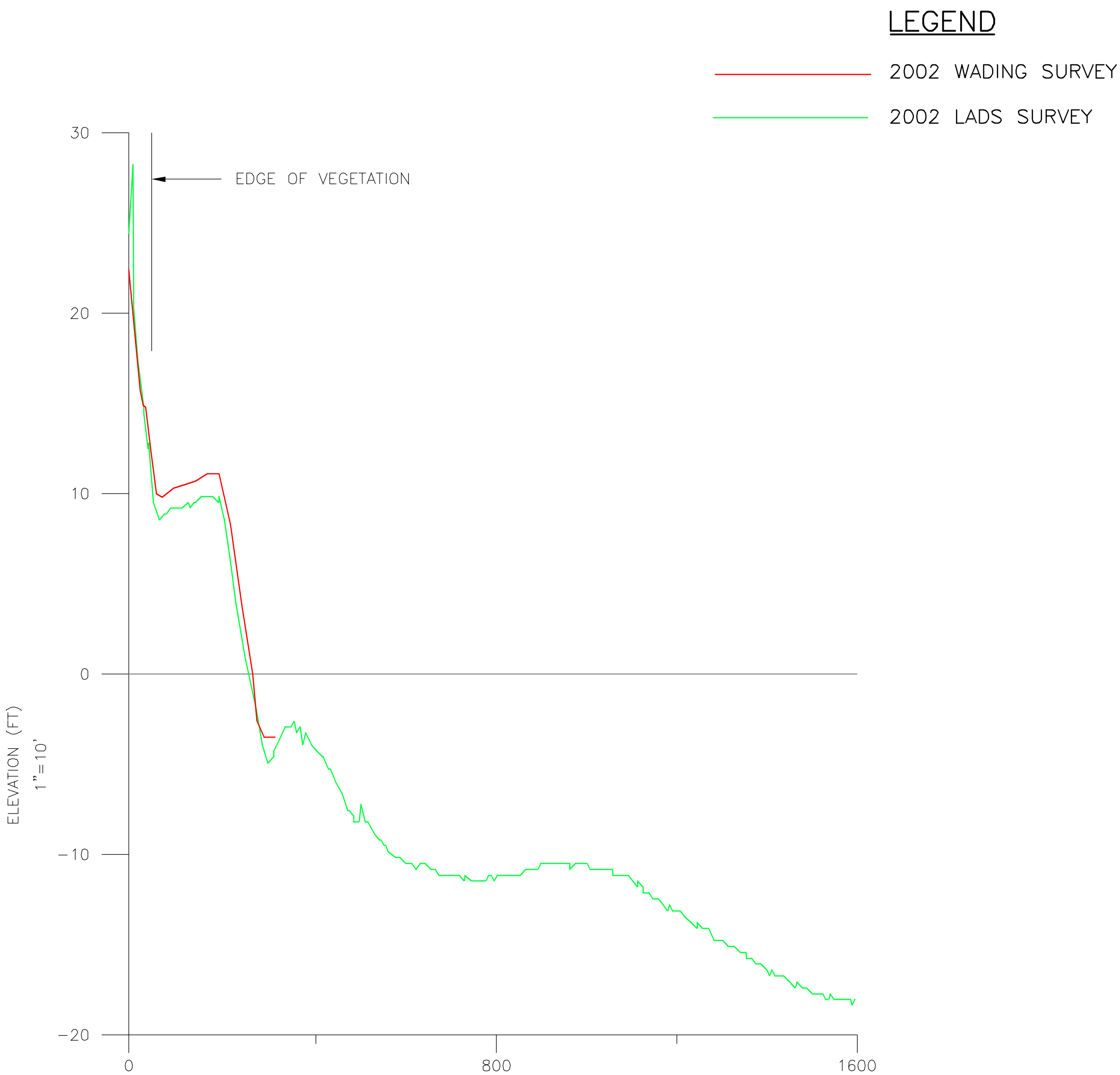
APPLIED TECHNOLOGY & MANAGEMENT, INC



04-965 Appendix C - Cross Sections.dwg R-34 4/26/05

Figure C-8
R-34 Profile Comparison of LADS Data and 2002 Wading (Traditional) Profiles
Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC



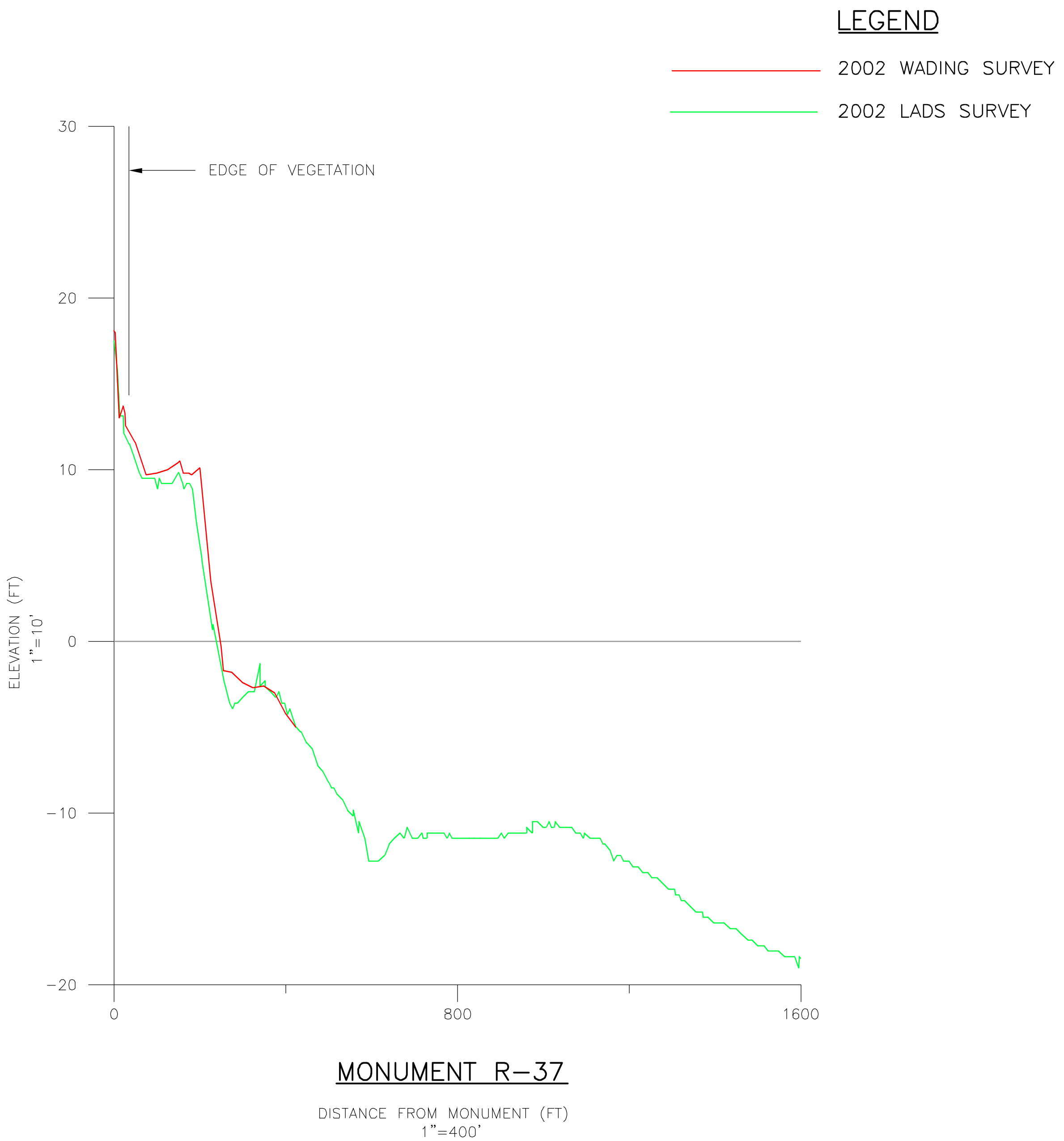
MONUMENT R-36

DISTANCE FROM MONUMENT (FT)
1"=400'

04-965 Appendix C - Cross Sections.dwg R-36 4/26/05

Figure C-9
R-36 Profile Comparison of LADS Data and 2002 Wading (Traditional) Profiles
Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC



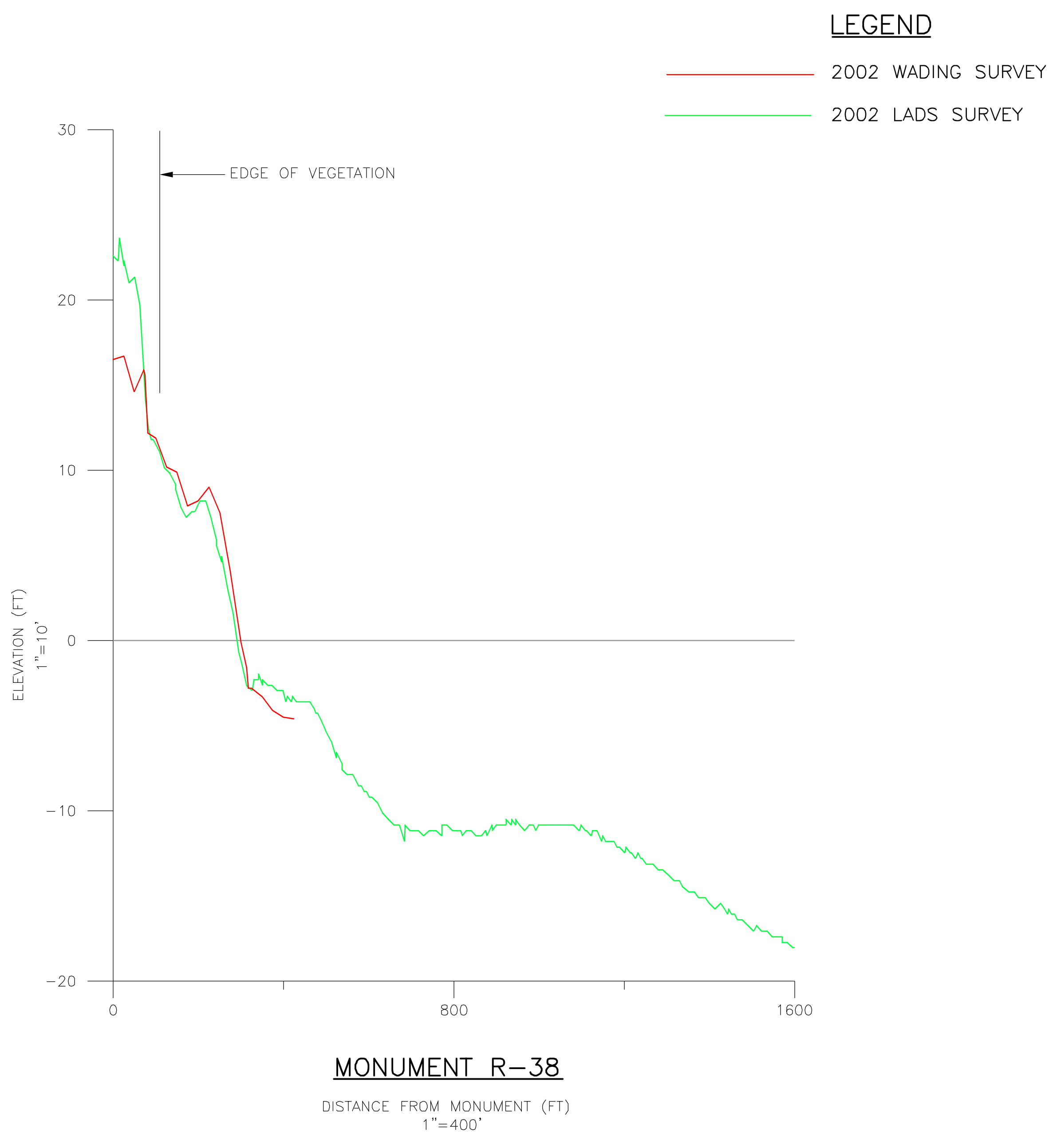
04-965 Appendix C - Cross Sections.dwg R-37 4/26/05

Figure C-10

R-37 Profile Comparison of LADS Data and 2002 Wading (Traditional) Profiles

Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC



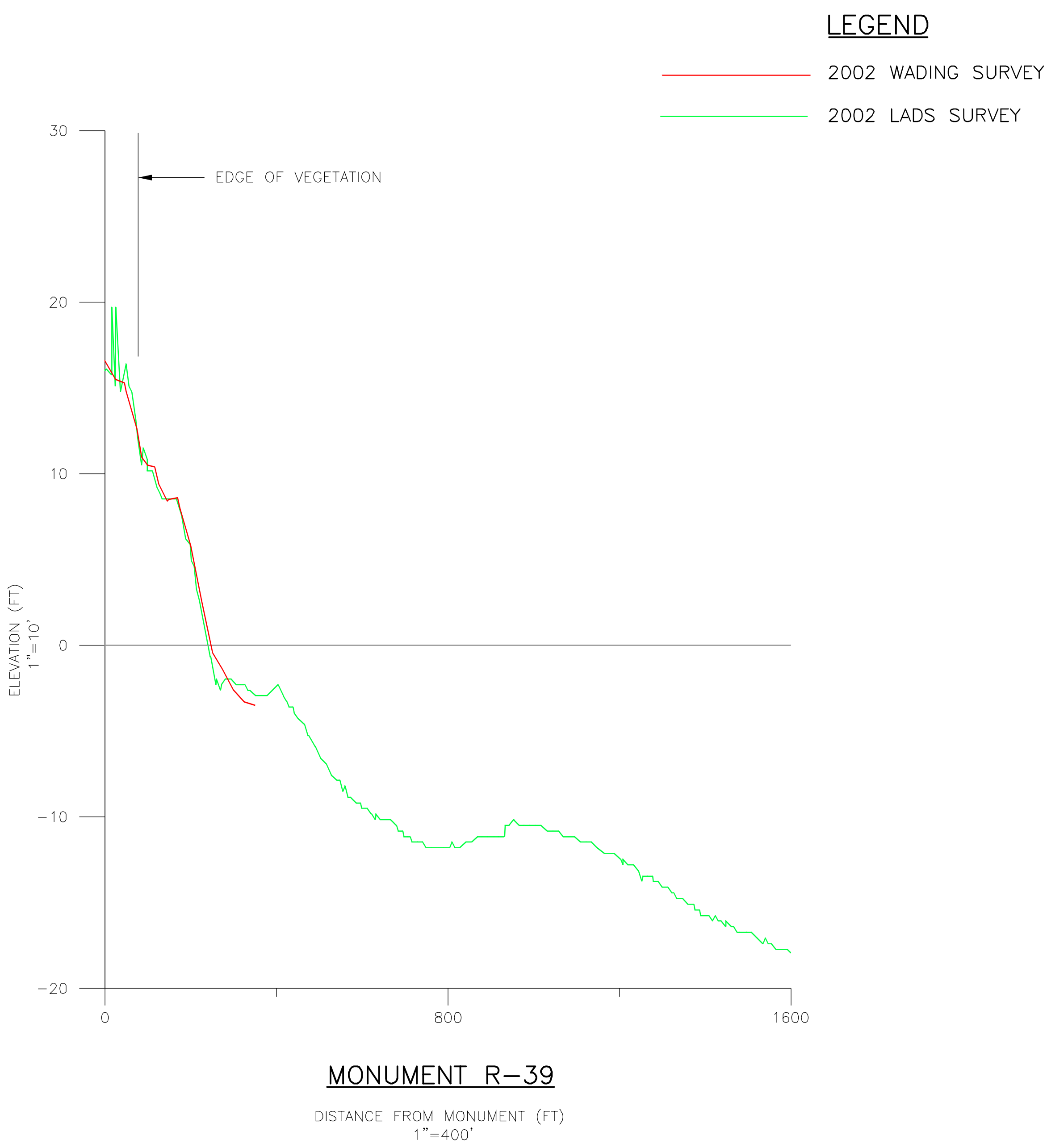
04-965 Appendix C - Cross Sections.dwg R-38 4/26/05

Figure C-11

R-38 Profile Comparison of LADS Data and 2002 Wading (Traditional) Profiles

Juno Beach Shore Protection Project

APPLIED TECHNOLOGY & MANAGEMENT, INC



04-965 Appendix C - Cross Sections.dwg R-39 4/26/05

Figure C-12

R-39 Profile Comparison of LADS Data and 2002 Wading (Traditional) Profiles

Juno Beach Shore Protection Project

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